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EDUCATIONAL PAPERS

BY

ILLINOIS SCIENCE TEACHERS.

I. 1889-1890

1891

J. W. FRANKS & SONS, PRINTERS, ENGRAVERS,

PEORIA, ILLINOIS.

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INTRODUCTION.

The Natural Science Section of the Illinois State Teachers' Association was organized during the session of the thirty-fifth annual meeting of the State Association, held in Springfield, Dec. 27, 28, 1888. At a preliminary meeting of teachers interested in science work, which was held in the office of State Superintendent Richard Edwards Dec. 27, a committee consisting of S. A. Forbes, of Champaign, B. P. Colton, of Normal, and Fernando Sanford, of Englewood, was appointed to report a plan of organization of a Science Teachers' Section of the State Association.

At another meeting held in the same room on the following day, Dec. 28, the committee submitted the following report, which was unanimously adopted:

"*Resolved*, That we organize as the Natural Science Section of the general Association.

That the section be limited, as to its subjects, to courses of study and methods of instruction in the following natural and physical sciences: Chemistry, Physics, Zoölogy, Botany, Physiology, and Geology, and as to its voting membership, to members of the general Association who teach any one or more of the above subjects.

That the President, Secretary, and Treasurer of the section act as an executive committee."

The officers elected at this session, and reëlected in 1889 and 1890, were S. A. Forbes, President, Fernando Sanford, Secretary, and B. P. Colton, Treasurer.

The papers read and discussed at the session of 1889 were:

President's Address,—History and Status of Public School Science Work in Illinois, by S. A. Forbes.

Pedagogical Function of Natural Science in Elementary Schools, by Chas. De Garmo.

High School Botany, by W. H. Hatch.

At this session a committee consisting of E. A. Gastman, Chas. De Garmo, B. P. Colton, W. H. Hatch, and Fernando

Sanford, was appointed to act in concurrence with the President of the section in preparing a course of study in elementary science for the different grades of the public school.

At the session of 1890, the papers read before the section were:

President's Address,—Pedagogical Contents of Zoölogy, by S. A. Forbes.

The Natural Sciences in Relation to the other Studies of the Common Schools, by F. M. McMurry.

At the request of a committee from the section that some phase of science work should be represented on the general program of the Association, Mr. Sanford was invited to read a paper on "A Course of Science Study for the First Four Years, its Aim, Material, and Method."

The committee on course of study appointed at the former session submitted the following report, which was discussed at length, and laid on the table for one year:

The Committee on Elementary Course of Science Study appointed by the Natural Science Section of the Illinois State Teachers' Association, met in the Harper House at Rock Island, April 24, 1890. There were present Messrs. Gastman, Forbes, Hatch, Colton, and Sanford. The members of the committee were practically unanimous as to the aims of elementary science instruction. Some of the purposes agreed upon were as follows:

Training to accurate observation, to careful comparison and generalization, and to correct and fluent expression;

To develop a sympathetic interest in Nature, for its moral effect as well as for its influence upon the intellectual activities;

To develop the causal idea, and to teach the uniformity of natural processes;

To furnish material for reading and language training.

It was the unanimous opinion of the committee that elementary science should be taught in some form in all the grades.

It was also unanimously agreed that zoölogy is, of all the sciences, best adapted for beginning this work with young children.

It was the opinion of the committee that for the first three years of school, ninety-five per cent. of the science time should be devoted to life studies, that for the next four years the science work should be related as closely as possible to the geography work, and that for the last year the physical sciences should be made more prominent, probably occupying one third of the science time.

E. A. Gastman, Chairman.
Fernando Sanford, Secretary.

The papers included in the present volume are those which have been read before the section, and the paper read by Mr. Sanford before the general Association.

S. A. FORBES, President,
Champaign, Illinois.

Fernando Sanford, Secretary,
Lake Forest, Illinois.

HISTORY AND STATUS OF PUBLIC SCHOOL SCIENCE WORK IN ILLINOIS.

S. A. FORBES, PH. D., PROFESSOR OF ZOÖLOGY,
UNIVERSITY OF ILLINOIS.

It is the purpose of this Society, as I understand it, to systematically investigate, discuss, and formulate methods of instruction in natural science, with a view to working out a body of sound doctrine and rational method, in respect to which we shall, if possible, become substantially agreed. These doctrines and methods we shall then try to bring to bear on the public school work of Illinois, in the hope that science work may be done here, in time, on rational principles and by methods approved by general experience. It is a work of progress and reform to which we have pledged ourselves; progress in the knowledge of principles and in the method of applying them, and reform in the science work in the public schools under our charge or immediate influence, and ultimately, as we hope, in those of the state at large.

In beginning a work we may very naturally ask ourselves, first, what has been done; and, second, what is next to do,— the answer to the second question dependent on that to the first,— and I have taken it for my part in the present program to prepare a brief outline of the condition of the science work in the public schools of Illinois at the present time; to explain and describe, as well as I can and as far as I understand the matter, the basis upon which it actually rests, and the forces which have built it up and hold it in position, and to sketch the history of its development. I very much wish that this task might be performed in a thorough-going and exhaustive manner, and I hope that this may yet be done by some one; but in the time allowable here for such a discussion I can only undertake to pick out a few items from the record, and to present them, if possible, in a way to make them available for our guidance.

The history of public school science work in this state is remarkable for one prominent and critical occurrence,— the

sudden introduction, by law, in 1872, of four new sciences into the list required for a county teacher's certificate. Although this legal enlargement of the public school course seems at first blush unwisely and even absurdly abrupt, and although it was unquestionably followed by many unfortunate immediate consequences, yet a study of the situation at the time, and of the previous history of the agitation of the subject and of the progress of science teaching in the state, will show that it was not as sudden and revolutionary a procedure as might be supposed. Many incitements to progress in this direction had long been at work in the public schools. A leaven of intelligence and awakening ambition had made itself felt for many years and in many ways,—through the reports and action of the State Superintendent of Public Instruction; through the State Normal School, opened in 1857; through the operations of the State Natural History Society, organized in 1858, and including many teachers in its active membership; through the young Industrial School, now the University of Illinois, established in 1867; and, long before that (in 1850 to 1854), through the remarkable educational campaign which gave origin to the University; through the more progressive teachers themselves—a few of whom, in city and village schools, were doing science work which it would be difficult to parallel for scope and thoroughness at the present time; through papers and discussions in the meetings of the State Teachers' Association and the State Association of Principals and County Superintendents; and through the educational periodicals of the day.

The first State Superintendent, Ninian W. Edwards, had declared, in 1854, in his first report, that the teachers of the state should have a "practical education, in which should be included not only what is commonly embraced in the common school course, but a practical knowledge of the sciences in their application to the ordinary pursuits of life."

Dr. Bateman, in his first report, the third of the office, had said, in 1860, "The senses are the pioneers of all knowledge. The dawn and activity of the perceptive powers are always antecedent to those of the reflective. The eye is the child's first teacher; the ear its next; and for several years the chief work

of education is to cultivate these organs." And, again, "It is the facts of the outer or material world, with which we must first deal, and the formation of habits of close and accurate observation is the great work of the elementary teacher." In 1862, he admonished the teachers of the state to "Keep the schools in close and living contact with the objective, the real; with nature and men and things; with the whole outer world and its moving panorama of events, as the theatre on which the pupils are to live and move and act." In his first announcement of the requirements for the state certificate, made in 1861, while omitting the natural sciences from the list of branches necessary for the diploma, he commended especially vegetable and animal physiology, physics, chemistry, and geology, as subjects with which the professional teacher should by all means have some acquaintance,—without which he must suffer great loss of power. In 1868 he foreshadowed the general introduction of the sciences, and directly paved the way for it, by making the state certificate conditional upon a satisfactory knowledge of physiology, botany, zoölogy, and chemistry. The new law of 1872 merely extended to the county examination the condition which had thus been for four years applied to that for the state certificate, except that physics was substituted for chemistry.

So far, then, as the State Superintendency is concerned, the development of the public school course towards a knowledge of nature and a preparation for science teaching, was a gradual and methodical one, proceeding by slow steps to an end held long and steadily in view.

Nor was the share of the first State Normal School in this work of progress an insignificant or indifferent one. Organized in 1857 under a law placing the elements of the natural sciences on the same footing as the other studies of its course, it had contributed its powerful influence, directly and indirectly, for fifteen years, to the education of the teaching body towards this end. By 1860, physiology, chemistry, botany, and geology were taught,—in a somewhat tentative way, it is true, and each but a term, while mathematics got five terms, geography three, and vocal music nine,—but the attempt was clearly regarded as an experiment. Says Principal Hovey, "We have

very few models in this department. Little is known of the possibility of so simplifying chemistry, for example, as to bring it within the reach of children. * * * The attempt, however, will be honestly made, at least so far as to put our pupil teachers in possession of the leading facts of these sciences, and the method of teaching the facts to children which seems to have the largest promise of success. The importance of the subjects would fully justify this course, even if it were not commanded by law." The details of the courses published show that the methods were not those of the modern science teacher,—a criticism applicable for some time thereafter. Botany was chiefly a study of text and the analysis of plants; the chemistry was apparently poured over the heads of the pupils like a shower bath, and there was no students' laboratory for many years; the physiology was demonstrated to the imagination only; and the physics was taught as a department of mathematics, by deduction from first principles, with a sovereign contempt for apparatus and experiment, not merely implied but vigorously expressed. Zoölogy was not regularly introduced until after 1872. Graduation theses were required in 1869 on some natural history subject worked out independently by the student.

To this special work of the Normal School the State Natural History Society largely contributed,—organized as it was only a year later, and having its museum in the Normal building. There Wilber and Holder and Powell and Thompson and Vasey worked, and created a little center of scientific activity, the spark of whose life has never yet gone out in Illinois. This body of amateurs, as it was at first, and this institution, as their museum later became, stood from the beginning in close relation to the schools. All the Normal men were members of the Society; Prof. Turner, of Jacksonville, was one of its leaders; the State Teachers' Association met with it at Normal in 1861, in a joint session for the dedication of its hall, and many of the teachers belonged to both organizations; it had for its principal object a natural history survey of the state, the publications of which it was hoped would furnish a suitable foundation for science work in the schools; it regularly assumed, as early as 1868, the duty of supplying natural his-

tory materials to schools prepared to use them; it brought the official geologist and entomologist of the state, and other scientific workers, into more or less familiar association with the public school teachers; and it helped especially to interest the outside public in natural history study and instruction.

And next we come to the State Industrial University. It was late in the field, but was compelled by the necessities of its existence to a vigorous activity in this direction. Organized especially to give instruction in the sciences and arts which underlie modern industrial life, it was evident at once that its attendance must depend largely on the general appreciation of a knowledge of science as a preparation for agriculture and the trades, and that the grade of its work depended immediately upon the previous instruction in the elements of science which its matriculates had received. Since it was, from the nature of the case, directly affiliated with the public schools, if there were no science in them there could none be required for its own entrance examinations, and it must itself do at first the work of an elementary school. Hence its regent and its trustees were earnestly active in this matter, and to its influence, I think, far more than to any other one thing, the final form of the law of 1872 was due. The science clause of this law was, in fact, introduced as an amendment* by one of the University trustees, Wilson Flagg, of Madison county (a graduate of Yale, an amateur botanist, a horticulturist, and an ex-member of the State Board of Agriculture), the chairman of the Senate committee on education at that time. But more important perhaps than this, the University had, most of all and earliest of all, exercised what we may call a powerful pre-natal influence in this matter; since the extraordinary campaign for an educational idea, which began with a convention of farmers, under Prof. Turner's inspiration in Putnam county in 1851, and ended at Washington in the passage of the land grant act of 1862,—since this agitation for the education of the mass of the people towards and not away from their future callings, carried always in its bosom, if not in its arms, the logical consequence that such an education must be had in the public schools

*The original bill contained, however, a requirement of qualification for the teaching of physiology and the laws of health.

as well as in the university, if it is to affect the welfare of the many and not only of the few. And this, I have come to think, as I have studied the record of the time, was clearly the main line of the movement which resulted in our legal enactment. The State Superintendents' reports, the State Normal School, the State Natural History Society, and the other things to be mentioned, were more or less powerful secondary aids; but the main result followed directly from the industrial agitation of the fifties. That reaching upward of the masses for more power and more light, which, spreading from Illinois eastward, gave us later the long line of land-grant colleges, and gives us now the State Experiment Stations, gave us also, as a sort of second growth from the seed first sown, the recognized acceptance of the natural sciences as a necessary part of the course of study in a true people's school. That this fruitful movement arose earlier and went further here than elsewhere, I attribute to the fact that it had here, in Prof. J. B. Turner, an able and devoted leader, who, himself an educated man, had those great human qualities which no learning can overlay, and which gave him access to all classes and power with all.

Of course I need not say that the schools and teachers, especially the better ones, shared in this steady growth and felt the stimulus of the light and inspiration centered upon them from so many sources. Beginning in 1851, we find a superintendent of Stark county saying hopelessly that, desirable as it is, he sees little prospect of a study of science in his schools, and, indeed, that some of his people still object to geography as contrary to the Bible, because it teaches that the world is round instead of having four corners; but in 1872, Principal Roberts, of Galesburg, says in his presidential address to the State Teachers' Association, that probably all the teachers really fitted to teach the sciences were actually teaching them when the new law went into effect.

Chicago has always gone her own way in these matters, within the state but not of it, and has to-day no natural science in her grammar schools, as I learned lately in response to a circular request for information. In her high schools, however, these subjects have had a place from the beginning, apparatus

for chemistry and for physics being supplied in 1856 as a part of the original equipment of her first high school. Indeed, in 1869 the general introduction of natural history throughout the schools was advocated at some length by the president of the city board, and the examinations required for admission to the high school at that time show that candidates had received some general instruction in the sciences of nature, apparently the object lessons of that day.

The Cook County Normal, opening in 1867 with a two years' course, gave object lessons for four terms and taught botany for one and physics for two. In the Peoria County Normal School, botany and physiology were taught in 1872, under Principal White. In the Aurora schools, Principal Jones had introduced in 1868 an elaborate course in natural science, beginning with the first year of the primary, and running through the high school. In the primary school, lessons were given on the human body and on animals and plants; in the intermediate, on the human body and the laws of health and in mineralogy and botany, the last studied with specimens in the pupils' hands. In the high school, more advanced and systematic work was done in botany, zoölogy, physiology, and physics. The work of this school was elaborately described by Dr. Bateman in his report for 1868, under the title of "a model graded school." In the Carrollton high school, botnay and physiology were taught in 1870 in the first year's course, and chemistry and physics in the second. In 1871 Etheridge published, as Superintendent of Bureau county, a graded course for his rural schools, in which object lessons ran through all the grades from the second to the sixth, and included something of anatomy and physiology, the zoölogy of the domestic animals, and the like.

In this same year two other model courses of instruction were made public; one for the lower grades and one for high schools, the former by White, of the Peoria County Normal, and the latter by Miss Grace Bibb, of the Peoria City High School, afterwards an instructor in the University of Missouri. In White's lower grade program one third of the time of six-to-ten-year pupils was given to oral object lessons; from ten to thirteen years, one sixth of the time to botany and physiology;

and from fourteen to sixteen years, one ninth of the time to zoölogy and physics. Two and a half years out of eleven were thus given to natural science,—in a ratio diminishing towards the high school. How different this from the common pretence of the present time that the natural sciences are higher branches, to be taught in the high school only! Miss Bibb's four years' English high school course gave more than one third of the time to physiology, botany, physics, chemistry, and geology; and her mixed course more than one fourth.

Roberts, of Galesburg, in the address already mentioned, allotted one third of the time in the high school to the sciences of nature.

In the Peoria High School, under Coy, in 1871, collections were made by the pupils, and museum cases were provided. In the Dixon schools the directors required, in that year, all teachers employed by them at the time and all candidates for positions there to pass examinations in physics, physiology, and botany, besides the studies required by law.

In all the abundant writing and discussion of that day, I do not find anywhere a note of discord. There was no opposition, objection, or even criticism of the movement, important enough to show itself in print.

To follow out this process of the growth and development of opinion, knowledge, and experience, during this period preceding the passage of the amended law; to show how the subject attracted continually greater and more important attention in the teachers' institutes and associations — county and state — in the gatherings of principals and county superintendents, and in the essays and addresses contributed to the two leading educational periodicals of the state — *The Illinois Teacher* and *The Chicago Schoolmaster* — would be to describe point by point the gradual dawning of the day, and would leave me no time to speak of the interesting effects which followed when the machinery of the law laid hold of the slowly rising sun, hauled it above the horizon with a single pull, and bade it shine there in full blaze without further loss of time. Some teachers were greatly rejoiced at this miraculous interposition in favor of their hopes and aspirations; but most seemed unmistakably startled, and evidently began to think that it was likely to be a

very warm day. "The natural sciences are upon us, and we must do the best we can," one such is quoted as saying.

That the law was a surprise to most of the teachers, neither expected nor wished by them, indeed, at the time, is shown especially by this circumstance: The original bill amending the school law of the state (but without the science clause, which was an afterthought) had been introduced in the previous session of the legislature, but not finally acted on; and a copy of this bill, published by State Superintendent Bateman, was widely circulated in 1871 among the leading teachers of the state, to call out an expression of their opinion. It was considered and reported upon by committees of the State Teachers' Association, of the Principals' Association, and of the County Superintendents, and important amendments were made to bring it into accord with their various views; but neither by the State Superintendent himself, nor anywhere in the published correspondence and discussion, so far as I can find, was any mention made of a change in the requirement for the teachers' certificate, or of the introduction of new studies into the common schools. The teachers were working toward this end and preparing for it, but they were not yet ready. This thing was clearly done by others, over their heads, and in advance of their wishes, although not really against them. Let us note especially the fact that the motive to the doing was not wholly the teachers' motive. The beetle that drove the wedge home and struck the blow that split the log was really the *practical;* these subjects were added to the public school course because it was hoped that a knowledge of them would help the people to live, and especially that the lot of the countryman and of the workman in towns would be ameliorated if they knew more of the facts and laws of matter and of life. And while this is clearly true, it seems also true that the common interest in the matter was not very great. It was an indefinite and half-hesitating sentiment, a diffuse and often ignorant inclination to believe, rather than a positive belief, which was made effective for the purpose it accomplished only because it had been fanned by agitation and focused by the energetic will and vigorous intellect of a few popular leaders. The situation was thus unusu-

ally interesting; and the subject is a fit one for a monograph. I can only briefly describe what followed.

The somewhat inconsiderate character of the original Flagg amendment is shown by the fact that, as introduced and as it passed the Senate, it made no exception to the requirement that every teacher in the state presenting himself for a state or county certificate must pass an examination in the elements of the natural sciences. A proviso permitting superintendents to issue, at the request of directors, certificates good for a year and in the district only, to teachers otherwise competent but not prepared for science teaching, was introduced as an amendment in the House and afterward concurred in by the Senate. These provisional certificates were, however, very naturally regarded as a makeshift and a badge of disgrace, a pledge of toleration only, and to the mass of teachers a full certificate seemed immediately indispensable. They were not content to take the provisional one for a year, and in the meantime to make ready for a genuine examination, but they must have a full certificate before the school year opened. The law went into effect July 1, and the schools generally began in September. There were two or three months, consequently, in which to learn four sciences, and, more than that, to learn to teach them; so county institutes had a "boom"–not very seriously affected by the fact that there were few competent to teach the new branches in them. The State Institute at Normal was thronged; and there all the sciences were taught, each forty-five minutes a day for three whole weeks—about eleven hours to a science, in all. The pupils were also advised to read a book, if possible, before coming to this institute.

The results of this wild work were not always perfect. A friend of mine, who was a village school director at the time, has lately given me an illustration. A teacher fresh from this Normal Institute was conducting an exercise in zoölogy, while the director sat, book in hand, supervising the same. The teacher read from his Normal note-book to his class something about the *candal* appendage of an animal. "Isn't that word *caudal?*" modestly asked the director. "O," said the startled scientist, "is it caudal in the book?"

It need not be said that the "graduates" from these "courses" usually passed their county examinations and got the coveted full certificate. For the makers of the law had either overlooked one most important point, or else had made a curious assumption. The fact was recognized that the teacher's qualification must be tested by an examination, but no one was set to examine the examiners. It seems to have been assumed that the county superintendent was necessarily and *ex-officio* a botanist, a zoölogist, a physiologist, and a natural philosopher; and that he was also a *teacher* of all the natural sciences. It may be surmised that the examinations were not usually dangerous, except, possibly, to the well informed. A lady of my acquaintance told me that a superintendent asked her to which class the turtle belonged. She answered that it was a crustacean, because it had a crust—thinking of pie-crust, probably, with its upper and lower layers and the filling between. "No," said the superintendent, "it's a mollusk, because it wears a shell." But she got her certificate.

And this indiscriminate scramble for the counterfeit presentment of the thing desired, was unfortunately not confined to the vacation work of 1872. I regret to have to record the fact that during the regular sessions of the Normal School a special class was organized of would-be science teachers, who were hustled through all the new branches in a single term. This was done with many self-accusing groans, and certainly with no unworthy motive, but because, all things considered, in the abnormal situation which had been artificially created, it seemed to those responsible the part of practical wisdom so to do.

Similar considerations must account for the action of some county superintendents, who made haste to renew, before July 1, all certificates of the good teachers in the r schools, so that for two years these might be at least nominally qualified for any situation. *The Schoolmaster* published some outline lessons in botany and zoölogy, two of the former covering about three pages of print, the latter more elaborate, an l then assured its readers that an eminent botanist had said that any teacher who had learned all which these two lessons contained should be considered entitled to the certificate, so far as botany was

concerned; and the editor said further that a diligent reader of his journal for the year should have no difficulty in passing all the natural science examinations. Even the requirements of the state superintendent's office fell far short of an ideal standard of proficiency. An elementary knowledge of zoölogy, to take an extreme example, was defined to embrace the chief distinguishing characteristics of the four grand divisions of the animal kingdom, a general knowledge of the five vertebrate classes and their principal orders, and some special acquaintance with insects and their chief divisions.

A single statement from the ninth superintendent's report is eloquent as to the results. During the three months after July 1, 1872, 3,975 teachers were examined in the natural sciences, and 3,114 passed.

But when this host of smatterers had been safely garnered in the schools, and the worst strain of the sudden pressure had been thus relieved, the work of thorough preparation began, or rather went on at an accelerated pace.

In one circular after another Dr. Bateman conveyed to teachers and school officers full but concise official directions, mingled with helpful suggestion and intelligent advice; while his next biennial report went like a trumpet call to all corners of the state, summoning the teachers to come up, like an army that had suddenly won an almost unlooked-for victory, and to occupy in force, and once for all, the new regions which had fallen under their control. The seventy-five pages of this report on the natural sciences in the schools deserve to become a classic

Dr. Gregory also, regent of the university, who, as state superintendent of Michigan, had strongly urged ten years before that the time for the old studies be abridged and the natural sciences be introduced beside them, contributed by lecture, circular, and personal advice, to give right direction to the rapid onward march; while the development of the scientific courses in the growing university helped to supply the greatest need of the time, that of trained and intelligent science teachers. The State Normal School at Normal continued its scientific work with the addition of a term of zoölogy, and with a great improvement in its methods in every branch.

To it was also due the continuance of the Natural History Museum as an independent establishment, after the death of the State Society and the departure of Powell, Vasey, and others, from the state. It contributed from its funds to the support of the educational work of the museum, giving it shelter, standing, and indorsement in the state when, practically abandoned by its founders, it had little else to go upon, and keeping it alive until an opportunity arose to get for it legal recognition as a separate institution. It also stood behind the two summer schools of natural history held at the museum in 1875 and 1876; schools at which Professors Wilder and Barnard of Cornell, joined with Burrill of the University, Thomas of the Southern Normal, and the writer, to give instruction for four weeks in zoölogy and botany to forty or fifty active and enthusiastic teachers. A greater supply and variety of marine objects for dissection were had at these inland schools than at their Penikese predecessor. From this museum (later the State Laboratory of Natural History) large supplies of specimens were sent out, and at the Bloomington meeting of the State Association in 1873, an organization of schools and colleges was formed for the collection and exchange of natural history material, this to pass through the museum at Normal for determination, preparation, and distribution. This work was kept up, the museum duplicates being added to the sets sent out until all the schools participating had respectable cabinets.

The educational journals of 1872 and 1873 were very largely given up to a discussion of science teaching; and those who imagine that the new movement went astray because of the ignorance of its leaders, will do well to look at the volumes of *The Teacher* and *The Schoolmaster* for those years. While the discussion of general principles sometimes lacked scholarship, it was nevertheless sound in the main; and the outlines of work and the formal lessons presented and the courses and detailed methods recommended, were usually the results of solid thinking and successful experience. Another class of helpful papers published at this time consisted of hints for self-help in field work and study, by those whose own experience had taught them how to instruct their fellows. In fact, all the educational institutions and associations of the day were worked at

full speed, vacations and all, to bring the mass of the teaching body up to the requirement of the law. So a great impulse was given to honest and earnest work—there is no doubt of that—and the science movement soon gained genuine strength and impetus enough to successfully endure the strain of the reaction which inevitably came when the slipshod work done by the incompetent began to bear its fruit. In many of the schools presided over by these teachers the sciences went out of the window almost as fast as they came in by the door—fortunately for such schools, because such teaching as these subjects had, could result at best only in an irreparable waste of precious time.

But time forbids my following the subject out in further detail, and I can only hurriedly sketch the present situation. In the first place, the sciences are hardly in the rural schools at all—those for which it was fondly hoped that they would do the most. This is partly due to a change in the law itself, made in 1874, chiefly in the interest of the low-grade teacher, limiting the requirement of these branches to the certificate of the first grade only. Most of the country teachers hold certificates of the second grade and cannot teach the sciences if they would. We have to reckon also with popular ignorance and with a sluggish public sentiment with regard to any aspect of the matter save the financial one. Among the better informed there is some uneasiness on this subject, and you can get a vote at any general country gathering favorable to the teaching of these branches in the country schools, if you ask for it, and because you ask for it, unless, indeed, it occurs to some one that this would raise the teachers' wages, and then you will probably have to fight for what you get. The sciences are not there, in short, because the country teachers cannot teach them, and because the average rural tax-payer does not care enough for them to be willing to pay their present cost. In the cities and villages of the better class the elements of these branches seem pretty firmly fixed in the high school course, but it is only the elements, and the work actually done belongs usually in the grammar school or still lower down. In now and then a town or city school, as at Aurora, Decatur, and Cairo, there is a graded and well-knit science course

throughout. I have some statistics on these matters which there is not time to give.

As to methods, they evidently differ widely. The lineal descendant and successor of the teacher who got his science in three weeks is still to be found in the school room, and he may teach from the book alone, but even he knows better as a rule; and where there is time and talent for the work, the teaching is often excellent. The right general ideas are common property, but they lack fullness and detail — in short, scholarship; and have not been worked out in systematic, well-knit, correlated methods and courses, adapted to the country school and to the various grades in city and town. The motive to the work seems now almost wholly pedagogical, and its economic basis has chiefly fallen away. This is partly due, I think, to that sluggishness of popular interest already spoken of, and partly to the fact that the actual work of the school has not commonly been directed to the economic end, and so the utilitarian results hoped for have not followed. The professional feeling of the teacher has sometimes kept him from this, and often he simply has not known how.

All this has, perhaps, a discouraging sound, as a report of progress after seventeen years, and yet it offers us this very great encouragement. The whole matter is now practically in the teachers' hands; and we are vastly better prepared in every way to meet the difficulties, to solve the problems, to apply and develop methods, to arouse the public interest, and to justify our work by its results, than we were in 1872. Let us natural science teachers band ourselves together, ground ourselves and each other, so far as we have not already done so, in a sound pedagogy based on a sound psychology; study the methods of foreign lands, where our subjects have been longer taught than here; agree, if possible, on courses and methods for the country schools and for each class of the graded school; examine and report upon the science work in our various towns, in our counties, and in our congressional districts; publish as fast as we are sure that our work is good and sound and true, and not before; and so lay together and build up, from year to year, by the method of coöperative effort, a solidly-based and well-wrought scheme of science work for the public schools of Illinois.

THE EDUCATIONAL VALUE OF NATURAL SCIENCE IN ELEMENTARY SCHOOLS.

CHAS. DE GARMO, PH.D., NORMAL, ILL.

(A) General Principles.

1. Like all other studies, natural science has an inherent value as knowledge, and a formative value as a means of mental discipline.

2. The most efficient method of teaching it must be determined by an analysis of those mental activities which lead to the best results in mental discipline. Further, that part of natural science which should be taught in elementary schools must also depend largely upon what can be made valuable for discipline, since this work is designed mainly to furnish a solid basis for all our future knowledge.

3. The first question to be decided, therefore, is, How does the child-mind act when study produces its best results in mental discipline? and the second is, What is the special function of natural science in this activity, and how can it best be realized?

4. Three different phases of thought may be distinguished in the study of any subject: 1. The Stage of Observation.—The acquirement and apprehension of new facts, more or less individual in their nature.—What is not acquired is nothing to mind; and what is not understood, to some extent, at least, may as well remain unknown. In elementary education especially, new elements of knowledge must be largely concrete, or individual facts, for the child is not able to apprehend underived generalizations. 2. The Stage of Generalization.— The conscious derivation of generalizations from these concrete data of knowledge.—Unless the concrete elements of knowledge are brought into relation, they remain isolated in the mind, and without significance. Generalization gives us classes and laws in natural science, definitions and principles in mathematics, rules of action in ethics, laws and principles in political and economic life. Without generalization knowledge would be a

wilderness of unrelated facts, in which the mind would be condemned to endless and aimless wandering. 3. The Stage of Application.—The application of derived generalizations to a wide field of appropriate new particulars.—This is illustrated in the application of a rule in arithmetic to a large number of problems. Without such application, any generalization would remain vague and indefinite; it would be a form with but slight content, nor would it be long remembered. A generalization not made by the pupil is to him an empty form; an unapplied generalization is a useless one.

(B) Educational Value of Natural Science, as tested by the foregoing Principles.

I.—OBSERVATION.

1. It is universally conceded that the stage of observation in learning is an important one, since all our knowledge starts with and presupposes the data furnished by the senses. The question is, What shall be observed in school? The ideas gained through the senses are symbolized in language by words. A word, however, partakes of the nature of a generalization, since it stands for it; it is individual, too, since it may be perceived by the senses, and since it applies to an individual thing. Words themselves may, therefore, to a limited extent, be studied and observed as individual or concrete things (inflection, etymology, spelling, etc.), but mostly they must be regarded as symbols of generalizations. If, then, the observation stage of thought is to receive the attention its importance demands, there is no efficient way but to begin with the study of things, and preëminently with the things of nature. These are all individual and concrete, whereas words are symbols, and, for the most part, symbols of generalizations.

2. *(a)* The most vital thing in observation is the training of the senses. This does not mean that the child's senses are to become better mechanical instruments. Nature has placed this matter mostly beyond our control. It does mean two things: (1), the habit of search for the facts of nature, and (2), a quickened perception of their significance. Then, to see well is not so much a mechanical, as a psychical act. In this sense, he

alone sees who apprehends. *(b)* We must, therefore, begin with the thoughtful observation of a single natural object, and on no account with some cut and dried classification of a text-book; *i. e.*, this inspiration must be inductive, at least while types are being learned. The object itself should be shown in all cases where practicable; otherwise good pictures may be used (Prang's Natural History Charts). Objects which cannot be produced or represented in pictures, should be reserved for later study, or, at most, read about in elementary books. Elementary science without objects is dry and unprofitable. *(c)* Not only must objects be carefully observed, but they must be described, since thought acquires clearness and precision by expression. A general plan of description is helpful. *(d)* In physics and chemistry, also, instruction must begin with the observation and apprehension of natural phenomena, not with laws. The simple experiment is the teacher's best pedagogical device for bringing natural phenomena to the attention of the children.

II.—GENERALIZATION *(Induction)*.

1. The peculiarity of elementary natural science as a means for teaching pupils to make valid generalizations lies in its concreteness and simplicity. Suppose the pupil has a hat-full of leaves or a large number of insects at hand for classification. There is at once a search for common characteristics as a basis. At first the classifications will be made according to likenesses most obvious to the child. A question by the teacher will lead to a closer observation and comparison, and a new arrangement of classes. This may be continued until the pupil finds the true scientific basis of classification. At every step of the progress the objects have been at hand, so that a concrete test of the validity of the generalization has at all times been possible. The same is true of physics, with this difference, that the generalizations are more abstract and the verification more difficult.

2. To be good for anything as a basis of mental discipline in the formation of correct habits of inductive reasoning, or of generalization, the objects themselves must be present. To begin with the memorizing of ready-made generalizations,

whether furnished by the text-book or by the teacher, is to sacrifice one of the main purposes of elementary science instruction; viz., the habit of making valid generalizations so far as this subject is concerned.

III.—APPLICATION.

1. In this stage of thought we find the bridge between the inner world of abstract ideas and the outer concrete world of things. He is the most successful man who is best able to embody his thought in action. The elementary stages of natural science furnish the pupil abundant incentive and opportunity for applying the generalizations, or abstractions, of thought to the concrete world of new particulars. After the proper classification of the leaves or insects above mentioned has been made, every new leaf or insect challenges examination and classification. When a few fundamental laws in physics have been discovered, every mechanical effect invites explanation. As in the stages of observation and generalization, so here, the peculiar virtue of a study of elementary science lies chiefly in the fact that it keeps the mental world in contact with the physical, thus tending strongly to prevent that divorce between the realm of ideas and that of practical affairs, so often seen in those who have long lived in the world of ideas alone.

2. It can easily be seen that here, too, if natural science is to have any disciplinary effect, so far as application to the concrete world is concerned, it must deal with objects themselves.

(C) Material.

1. It does not fall within the scope of this paper to prepare an elementary course of study in natural science, but rather to run the main lines, along which instruction should move, as indicated by a pedagogical analysis of the subject. The most superficial examination shows the folly of allowing elementary natural science to consist in memorizing zoölogical and botanical classifications as presented in school text-books. This must be condemed on all three counts,—ready-made schemes of classification, even when their bases are mentioned, furnish no material for observation, hence are useless as a

foundation for ideas; they furnish no drill in inductive reasoning, since the generalizations are memorized from a scheme at the beginning; they furnish no incentive to application, for they have been learned and recited as if they had nothing to do with actual nature. A thoughtful mind might possibly get some discipline in thinking through the mental movements of the author when he arrived at his results, but to the ordinary child such study is as barren as the method of teaching is easy.

2. We have found that every stage of the mental movement in efficient learning has demanded the actual objects. How can one observe without anything to examine; how can a child reason to valid generalizations in natural science if he has no individual things to reason from; and how can a child be trained to make constant and ready application of the results of his reasoning in natural science if no objects are ever present?

3. Lack of time and knowledge on the part of the teacher, and lack of material of certain kinds, may make it very desirable that that which can be taught from the objects themselves should be supplemented by information gained from elementary science books. Of these there are now a goodly number admirably adapted to this purpose.

4. The objects chosen should be such as can be found on all sides, and such as can be most easily apprehended (domestic animals, insects, common flowers, leaves, table-salt, etc.; not infusoria or other miscroscopic forms). In physics and chemistry we should choose what is attractive and easy to understand, and first of all that which helps to understand and to explain the most common phenomena; also what is important in domestic life and in manufacture (the lever, the cord and pulley, wheel and axle, etc.; the construction of domestic implements; the ventilation of rooms, etc).

BOTANY IN THE HIGH SCHOOL.

W. H. HATCH, SUPERINTENDENT MOLINE PUBLIC SCHOOLS.

It is needless, with the company here to-day, to urge the claims of botany to an important place in the high school curriculum. The questions that present themselves to us are, what to teach and how to teach it.

The end to be attained should be clear in the mind of the teacher before beginning any work. The analysis of fifty to a hundred species, or the preparation of a herbarium of like number, is, I am glad to say, no longer considered all there is to be done in the study of botany in secondary schools. There is a life, with all its beautiful phenomena, a physiology, with all its questions of function. The student finds that the subject of study is life. The characteristic of a living thing is that it has the power to respond to external influences. The means and methods by which it does this, furnish the basis for work in biology. Life, and consequent growth and reproduction, furnish the problems to be solved. The high school student should become familiar with the simpler phenomena of plant life, such as the effects of heat, light, moisture, and gravity, the appearance and work of chlorophyl, the plant cell, tissues and their functions, assimilation, respiration, and methods of reproduction. With these objects in view, how shall we proceed?

Dr. De Garmo has spoken in his paper of the three phases of thought in science work: observation, generalization, application. He has also said that "to begin with the memorizing of ready-made generalizations, whether furnished by the text-book or by the teacher, is to sacrifice one of the main purposes of elementary science instruction; viz., the habit of making valid generalizations so far as this subject is concerned." Observation must precede all else. The student must then, *first of all*, be brought face to face with the facts and phenomena. Later he may receive facts second hand, but not in the first and most important steps.

A late writer has well said that in the *beginning work* in natural science the text-book that can be used by the student without the object to be studied before him, has no place in our secondary schools. The work must begin with the object in the hand of the student. I emphasize this, since so many of our high school courses call for the beginning of botany in the winter, or at least before plants appear in the spring. I am convinced that the spring is the time to begin. All nature is awaking from her long sleep, and the children are intensely interested in that which should form a large part of our study—*growth.* The average lad is intensely interested in all the manifestations of life that come under his notice; and when something new presents itself he wants to know what the thing does, how it does it, and what it does it for.

These are the problems of vegetable as well as animal physiology in school-boy vernacular, and to successfully instruct the mind of youth we must recognize the interrogation points that stand out with such prominence.

Another reason for beginning in the spring: While I do not think the order is important, I am convinced that the work should begin with the entire plant as a unit—the individual. The work may begin with the lowest orders and work up to the highest. There are many good teachers who prefer this, and it may work well where the pupils have sufficient maturity to overcome the many difficulties presented at the beginning. The *method* is far more important than the *order.* In his first steps there is danger of too much rather than too little direction. The average student, Polonius-like, can be made to see almost anything, especially under the microscope. We want, first of all, careful, accurate, and *honest* observers.

The books to be used are of three kinds:

1. The working manual, which permits the child to proceed only with the object before him.

2. The library of reference, containing special books on the various departments of the subject.

3. His note book, which will contain the results of his own research, supplemented by his lectures and reading.

A method that has been tried and found successful is always of more value than a theory that has found its way no

further than paper. All work suggested in the following outlines has been tested in the class room.

Please remember that we are dealing with children beginning high school, age fourteen and fifteen. No preliminary work with book has been done. The entire plant is placed before the pupil. In the choice of material we are compelled to use what we can get. Our first plant is far from typical. I am not sure, however, that there is not a gain in this in the end, as the student is introduced to facts, not theories, and he soon learns that most important lesson, viz., the danger of generalizing from a single fact. We use our earliest blossoming plant, the Hepatica, or *Anemone acutiloba.*

I will give the first simple outline in full.

(Each child has an entire plant.)

1. The **thickened stem** (root-stalk).
2. The **Fibrous Roots** growing downward from the stem.
3. The **Leaves**.
4. The **Flowers** on the summit of branches of the stem.

I. THE STEM.

1. From what part of the stem do the roots grow? the leaves?
2. Beginning at the lower end, remove the roots and leaves. Notice in the **axils** of some of the leaves, branches bearing flowers. Remove them. Lay the parts carefully aside.
3. Remove the scales on the upper part of the stem and find the **growing end**.

II. THE ROOTS.

1. Note *(a)* their shape; *(b)* their color.
2. Do they branch?
3. Compare them with the leaves in length and number.
4. The roots are:
   (a) Hold-fasts; *i.e.*, they support the plant and fasten it in the soil.
   (b) Feeders; *i. e.*, they collect nutriment from the soil.

III. THE FOLIAGE LEAF.

1. Note the parts of the leaf:
   (a) The stalk or **petiole.**
   (b) The expanded portion, the **blade.**
   (c) A pair of appendages at the base of the petiole, **stipules.**
2. Draw the leaf, naming the parts.
3. Did this leaf grow this season? (Young leaves will be found starting from the stem.)

IV. THE FLOWER.

1. Note that the flower is borne on a branch of the stem, the flower stalk or **peduncle.**
2. Note three green leaves on the peduncle a little below the flower. Pick one and compare in size and shape with the foliage leaf.

   A small leaf on a peduncle is called a **bract.** Draw.
3. Note the leaves of the flower, the **floral envelopes.**

   How many? Draw one and compare in size, shape, and color with the foliage leaf and bract.
4. Within the floral envelopes find two sets of organs; the outer called **stamens**, and the inner, **pistils.**
   (a) The two parts of the stamen are the stalk or **filament**, and the yellow **anther.**
   Draw and name parts.
   (b) Examine with glass the pistil; note the enlarged base, the **ovary**; the upper, contracted portion, the **style**; and the tip or **stigma.**
   Draw and name parts. Pick open an ovary and find the young seed, the **ovule.**

POINTS FOR STUDY.

The stem is the main axis of the plant.
The stem terminates in a growing point.
Members of the stem are branches.
Appendages of the stem are:
(a) Roots; *(b)* Leaves.
What kind of leaves are found on the stem?

In a similar manner we treat several of the familiar spring-blossoming plants, choosing such as will best familiarize the pupils with the parts of the plant and its method of growth.

At any convenient time after the dissection of a few plants, one or two lessons are given in the use of the analytical tables; the analysis being made from their notes. Experience shows that but little attention need thereafter be given to analysis, except to see that the results are correct, as the pupils carry it on from choice.

The first work of the fall is a careful dissection of the sunflower, introducing the student to Compositæ, after which the average boy or girl usually undertakes the classification of the asters and solidagos with all the guileless confidence imaginable, but soon retires from the conflict vanquished, learning a wholesome lesson in his defeat.

At this time and in the spring he undertakes the further study of plant anatomy and physiology. He makes a study of the fibro-vascular system, using first the plantain, in which the bundles are readily traced and easily removed. In the root-stalk their arrangement and shape are easily made out. This is supplemented by the examination of the bundles in various dicotyls. Their location and plan of distribution are associated with their function. The meristem tissue is shown by carefully peeling the bark from twigs of woody growth. The comparison is then made with the arrangements of bundles in monocotyls, using Trillium, etc.

The leaf affords an excellent opportunity for the study of the relation of structure and function. I will give in full the outline as used.

LEAVES.

The cultivated geranium leaf was used in the preparation of this study, but others may be used in the dissection. Nearly all of this work may be done in the winter.

I. THE STRUCTURE OF THE LEAF.

1. Notice:

   (a) The expanded portion, the **blade**.

   (b) The frame-work, composed of **ribs and veins**.

   (c) The foot-stalk, **petiole** (sometimes wanting).

2. With a needle, tear off some of the thin skin, **epidermis**, that covers the blade. Does it also cover the **petiole?**

3. Peel off carefully a piece of the epidermis from the lower surface of the leaf; examine under one-fourth inch objective:

   (a) It is made up of a layer of cells of irregular shape.
   (b) Note the **hairs**, composed of lengthened cells placed end to end.
   (c) Find small openings (**stomata**) in the epidermis. (See figure of stomata in any botany.)
   (d) Draw, showing cells, hair, and stomata.
   What is the color of the epidermis?

4. Soak a portion of the green leaf in alcohol. The alcohol is colored green. This green coloring matter in plants is **chlorophyl.** Mount a thin vertical section of the leaf and find the chlorophyl grains (small rounded bodies). Use $\frac{1}{4}$-in. objective.

Some of these were probably seen during examination of the epidermis. (If desired at this point, a more extended study of chlorophyl may be made, using a plant of moss.)

5. Split the petiole and notice the white threads running through its entire length. These are the **fibro-vascular bundles.**

   (a) Trace the bundles into the veins of the leaf by splitting the petiole and veins.
   (b) Examine (under $\frac{1}{4}$-in. obj.) a thin longitudinal section of the petiole. Note that the bundles are composed of long ducts of different appearance, some of them with spiral bands.
   (c) Some of these bands may be drawn out as spiral threads if the petiole be carefully pulled apart.

6. In the above study we have observed that

   (a) The leaf is a thin layer of cellular tissue consisting of chlorophyl-bearing cells.
   (b) This cellular tissue is covered on both sides by an epidermis.

(c) Through this epidermis are openings (stomata) to the outside air. They are more numerous on the under side.

(d) Numerous ducts run from all parts of the leaf through the veins and petiole to the stem.

II. THE FUNCTIONS OF LEAVES.

The principal work of the leaf is to form starch from carbon dioxide (CO_2) and water (H_2O). This process is called **assimilation.**

1. The CO_2 is contained in the air, which enters the leaf through the stomata.
2. The water comes from the roots through the walls of the wood cells and the ducts.

   There is a continous evaporation of water through the stomata, and a continuous flow of water is kept up through the plant.
3. When the sunlight shines on the chlorophyl it decomposes the CO_2 and H_2O. Some oxygen escapes and the remaining elements unite and form starch ($C_{12}H_{20}O_{10}$). Chlorophyl has no power to do this except in the presence of light.
4. This starch is afterward changed to glucose, inulin, etc., the organic substances of which plants are composed. (This process is called metastasis.)

   Simple experiments illustrating these points may be found in Bessey's Briefer Course, pp. 75-77 and 85-86. The teacher should direct the pupil which to perform.

III. THE FORM OF THE LEAVES AND THEIR ARRANGEMENT UPON THE STEM.

1. From the structure and functions of leaves we can determine the laws which govern their various forms and arrangement.

LEAVES ARE ARRANGED

(*a*) To expose a large surface to the action of sunlight.

(*b*) To allow free circulation of air among the leaves.

(*c*) To allow the blade to be tossed about by the wind, as this assists the circulation of air and thus increases the evaporation of water.

(*d*) To afford a strong frame-work for the blade and allow the ducts to communicate with all parts.

2. Notice the application of these laws:

(*a*) To the poplar.—Pick some leafy twigs. Turn them upside down on a small table and spread out the leaves. They about fill the space without overlapping. The petioles are long and flattened laterally.

This makes the leaves sensitive to the slightest breeze. (Quaking aspen).

The long mid-vein gives off branches which continually divide until the whole surface of the leaf is finely reticulated.

(*b*) To the grass.—Grass usually grows in tufts and the leaves are long and narrow. Why? Notice the long attenuated apices and how they move in the wind,

(*c*) To the plantain.—Here there is a rosette of leaves about the stem near the ground. The flower stalks are naked and do not shade the leaves. The petioles are broad, allowing motion only up and down.

Compare the dandelion and other similar plants.

(*d*) To the catnip.—The lower leaves are largest and their petioles are largest. Each pair is at right angles to the next above or below. Try to insert a leaf on a catnip stem and not have it shaded by one already there? Note that the catnip leaf is notched on the margin. The veins run into the points. It is very common for the margin of leaves to be notched between the ends of the veins. The larger points will usually be at the end of the larger veins.

(*e*) To the butternut.—The leaves are large on this tree, but each is divided into a number of **leaflets** to allow the air to circulate. Such division of large leaves is common, and such leaves are said to be **compound** in distinction from those with a single blade, **simple leaves.**

(*f*) Go into the woods or garden and apply these laws to any plants you find and bring the results of your observations to class.

3. Many special causes determine the forms of leaves in particular plants.

Note the leaves of a pea. They end with a tendril to enable the climbing plant to cling to its support.

The pitcher-shape leaves of the pitcher plant are adapted to hold water and to capture insects. (Gray, p. 65.) The reason for peculiar forms should be sought. Read Gray, pp. 62-65; Bessey, pp. 269–275.

4. The form of leaves varies even in the same species and the same individual, but is constant enough to afford valuable characters for the determination of species and is used for this purpose. It becomes necessary, therefore, to gain some acquaintance with the terms used in describing leaves.

IV. HOW LEAVES PROTECT THEMSELVES.

Dangers threaten leaves from

1. Depredations of insects, etc.
2. Too much water.
3. Too rapid evaporation.
4. Too strong light.

The means used by the leaves for protection are the epidermis and its appendages—hairs, prickles, glands, and stings. Their uses may be determined by the following observations :

1. Strip the epidermis from a leaf of live-forever and hang it in the sun by the side of one that retains the epidermis. Note the rate of drying. What is the use of the epidermis to this leaf ?

2. Examine a thistle and a nettle. How do they differ in the means of protection from animals ?

3. Notice the curling of the leaves of a tree in strong sunlight. How does the position assumed protect them from the sunlight ?

4. Dip leaves of different kinds in water.
   Is there any difference in the ease with which the surface may be made wet ?

   (See Sachs's "Physiology of Botany," p. 117.)

5. Notice the white powder covering the leaves of many willows. Of what use is this ?

6. Examine hairy plants. Are the hairs more numerous in young or in old organs ? Which need the more protection? Is the upper or the under surface more hairy? Why ? (Hairs protect the stomata but hinder the access of sunlight to the chlorophyl.)

7. How does the cactus defend itself ?

8. Compare the taste of different leaves—grass, oak, wormwood, etc. Does the taste of the leaf ever afford protection ? From what ?

9. Carry these observations as far as possible and write results in your note book.

Many of the interesting questions of life may be studied in such a plant as *Marchantia polymorpha*. The student, with plant in hand, has placed before him such questions as these:

Why is the stem horizontal ?

Why are the pedicels vertical ?

In attempting to answer these questions he finds that the liverwort is sensitive to light and gravity. What organs place themselves parallel to the direction of light and gravity ? What transverse ? He compares the upper and under sides

of the stem and brings out **dorso-ventral** structure. This structure is compared with that of the vertical organs, and **radial structure** is developed. He seeks illustrations of dorso-ventral and radial structure in the various familiar plants. Do they correspond in position with like organs in the Marchantia? He develops the law of position in relation to the forces of light and gravity. He then makes a careful study of the stem, and, using ¼-inch objective, finds the stomata with their guard cells. By cross section he finds the air spaces communicating with the stomata, and the chlorophyl located nearer the upper surface. In his study of the leaf he has learned of the process of assimilation. He is therefore prepared to consider such questions as these:

The presence of great quantities of chlorophyl indicates what function for the stem? Why is the stem flat?

Which surface is the chlorophyl near?

On which surface are the stomata? Why? What is the use of the air spaces?

The plan of this plant is then compared to that of a plant of moss, in which the chlorophyl-bearing organs are lifted into the air and spread out by the stem. The two plans are then compared as to their economy.

One of the most interesting lessons that I have seen the class undertake is intended to illustrate the adaptation of means to accomplish certain purposes. It is a study of cross fertilization as illustrated by the pansy, and was suggested by Sachs in his "Physiology of Botany." The pupils are supplied with the flower only. A dissection shows all the parts and their shape. They observe that the spur is suspended and that the cluster of anthers part sufficiently to allow the pollen to fall into the groove leading into the spur. They see the filaments projecting into the spur and forming glands for the secretion of nectar. Then taking a fresh flower, the dissecting needle is thrust into the groove as a bee would thrust its proboscis in search of nectar. The needle, carefully withdrawn, brings with it some of the pollen. It is inserted into another flower and the student observes that the lip on one side of the stigma wipes off part of the pollen and causes it to fall into the depression in the stigma. When the needle is withdrawn he ob-

serves that the same lip prevents the pollen from falling on the stigma of its own flower. Thus cross fertilization is secured. I believe that such lessons as these will lead the student not only to observe carefully but to seek reasons for what he sees. The rough question of the boy "What's that for?" is a pertinent question to his mind and one that we do well not to ignore.

PEDAGOGICAL CONTENTS OF ZOÖLOGY.

S. A. FORBES.

The question whose discussion I wish to open to-day is that which every one must answer first of all who has to arrange a school course in zoölogy: What part of the subject matter of that science is best adapted to the teacher's special ends?

The aim of the zoölogist is to form, as nearly as possible, a complete and accurate picture of the animal life of the earth, to exhibit its internal relations and those to nature at large, and to account for it by tracing its history in general and in detail and by ascertaining the causes which gave it being and form. A great part of the motive to the labor lavished on this subject is the commanding interest of the including subject of life in general, its laws, its origin, and its destiny. The pursuit of this science may tax to its utmost, it seems to me, every power of the mind, and the knowledge of life it leads to has a great and primary value and interest to us all. It will not do, consequently, to look on it as an apparatus for mental gymnastics only, and neither will it do to look on it, for our purposes, as a body of valuable knowledge and nothing else. We must see both what it contains that our pupils ought to know, and what the pursuit of it requires that they ought to learn to do. As a body of knowledge, I would divide it according to its relations to the labors, the pleasures, the conduct, and the thought of man,—according to its industrial, its emotional, its ethical, and its intellectual values.

On the industrial value of zoölogy I speak with the feeling derived from long experience. It is true, for example, in my judgment, that the insects of the state of Illinois derive as large a profit from the agriculture of this great agricultural state as do the farmers themselves. It is probably true that they cost the state at least half as much as the whole system of its public schools, and a very large percentage of this great loss

might certainly be prevented, if we could bring the economic facts of this one department of zoölogy into the store of common knowledge at the command of every pupil in the town and country school. That we fall far short of this requirement, I have evidence every time that I address a gathering of farmers or horticulturists. A large farmer of this state, a gentleman of education, and a leader in farmers' organizations, mistook not long ago, in my presence, the plum curculio for the chinch bug. The Hessian fly is not known at sight in the adult stage, or in the main features of its biography, to one in hundreds of those who suffer pitifully from its ravages. The simplest elements of entomological instruction, put in the plainest of English speech merely confuse the average listener, so unaccustomed is he to facts or ideas drawn from this department of knowledge. It is not beneath the dignity of the public school, or of the teacher of the public school, to help to lift the burden of such destructive ignorance from the minds of the largest and most important class of the people of this state. So I think we should list, as important knowledge, certainly to be closely scanned by us in drawing up our courses in zoölogy, all matter concerning especially the birds, the mammals, the fishes, and the insects of the state, their distinguishing characters, their biographies, their habits, their relations to nature generally and especially to man, an acquaintance with which would be directly or indirectly useful to the average citizen.

It is the defect of the more modern laboratory method in biology that it tends to make near-sighted minds. One may keep his eye at the microscope so constantly and so long that he cannot see without that instrument. I know zoölogists who must have nature boiled in corrosive sublimate solution and fried in paraffine and sliced by a microtome before they care for it. There is little probability that matters will go to this extreme in a public school, and yet they may be easily made to tend too far that way. The children must be drawn towards and not away from the woods and fields and waters, and must be led to see more clearly that nature lives and feels and acts, and links herself to human interest and sympathy in the strongest and the subtlest ways; that a man cut off from fellowship with the creatures of the open air is like a tree

deprived of all its lateral roots and trimmed to a single branch. He may grow down and up, but he cannot grow out. His resources of enjoyment are so narrowed that he is often an object of pity when seen away from the city street. The ordinary tourist in our national park—one of the loveliest spots on earth—rushes from hot spring to geyser and from geyser to cañon and away again behind six-horse teams, often grumbling then that there is not a locomotive to whisk him about; and if he lingers at all by that lovely wayside, it is only to fish. It is not creditable that their education should leave our well-bred men and women so blind and deaf to the significance and beauty of the world of life. The greater part of the emotional, the æsthetic value of zoölogy is lost if the door of the class-room is shut. A personal knowledge of the habits and activities of animals, and a habit of a sympathetic observation of them, are very valuable elements in the result of the skillful teaching of a well-selected course.

And if to these we are able to add the clear perception of the unity of organic nature, which adds to every part some portion of the interest belonging to the whole, which accustoms the mind to travel quickly along the threads of vital connection between the single form and the complex living group of which it is a member, our pleasure in it is intensified and lifted to a higher plane. And if, again, to this idea of the unity of living nature as it now exists, we can add an intelligent conception of the continuity of its present with its past, the idea of a progressive development of life, and learn to recognize its evidences from time to time in the animal forms examined, then the single animal is no longer a temporary trifle, but a long biography, a fragment from the history of life upon the earth. We cannot afford to overlook or ignore, in our teaching, the interrelations, the inter-actions of animals as members of natural living groups, or the value of each living thing, by nature's standards, as the product of a long struggle towards perfection.

There is also a curious fascination in the unrestricted exercise of the exceedingly human propensity to classify, which, when fully developed and disciplined, makes the taxonomic specialist,—a fascination which grows with what it feeds upon,

and which has its cause and justification in some of the most characteristic tendencies of the human mind. In the deliberate and attentive comparison of form with form and structure with structure, and in their orderly arrangement in complicated groups and grades of groups, in the perception of general features running through a mass of things otherwise variously unlike, and in the mental organization of the whole into a compact body of knowledge, the mind is simply performing on things the processes which when applied to ideas we call the recognition and discovery of laws. It may easily be carried too far, but besides affording a certain peculiar mental pleasure, it furnishes a highly valuable discipline. We cannot rationally justify ourselves in tabooing as worthless a practical knowledge of the classification of animals. The young laboratory specialist may sometimes tell you that not only are Linnæus and his followers dead, but their works and methods also have died after them; but in so saying he is trying to impose on the general and elementary work of the schools the limitations of his own special training and his own personal bias. He is simply teaching you devotion to a fad.

But much more important, I think we will all agree, than those parts of our science which have an economic and æsthetic bearing chiefly, are those which familiarize the mind with the larger generalizations of the science of life. The longer I teach the more I use the technical processes of zoölogy as a scaffolding, and its technical facts as a foundation and support for a body of general laws, built up in an orderly manner from almost the first beginnings of my course, and illustrated at every turn, until they are as plain and familiar as the elementary laws of numbers. Let me catalogue a few such generalizations.

1. The law of progress by differentiation and specialization of structure, and (2) the corresponding law of the physiological division of labor. 3. The law of the progressive development of the single animal from the single cell by uniform stages to its adult condition. 4. The law of the agreement of this individual development with that of the group. 5. Next, and really based upon the foregoing, the well-known doctrine of homologies. 6. The idea of a complication and

differentiation of the invisible, or at least hitherto unobserved and possibly molecular, structure of unicellular animals as compared with the visible organic structure of the higher forms,—easily got at by way of the theory of isomorphs in chemistry. 7. Next, the universal correlation among animals, of structure, habits, and surroundings, and (8) the law of accommodation according to which the animal organism can adapt itself within certain limits to changes of condition, or, in some cases, almost without limit if the changes are gradual enough. 9. The law of spontaneous organization in a so-called life group or animal society, by a mutually enforced adjustment, among species, of rates of reproduction and destruction. 10. Then the fact of animal evolution, and such of its methods as are commonly considered by naturalists as settled beyond dispute. 11. The explanation and illustration of the processes of life in its simplest forms, and the relation of life to organization. 12. The physical and material conditions essential to the manifestation of life,—such as temperature, moisture, and a complicated and unstable composition of its material basis. 13. The law of the limitation of growth, dependent upon the mathematical relation of the surface of a body to its mass. 14. The correspondence between colonies of animals of various grades of organization, and of the single animal body with its various organs. 15. The gradation and development of mind in animals, through a differentiation and specialization of capacities.

Such is a partial list, in rather technical language, of generalities which, stated baldly, would of course be uninteresting, and unintelligible indeed, but which if skillfully developed in the order of their difficulty and repeatedly brought to the attention by new and varied illustrations, may be made as easy of acquirement as those of any other subject. So used they give both depth and elevation to the work, and should at least be always in the teacher's mind as centers round which the operations of his class should be made to revolve.

The peculiar ethical effects of zoölogical study are to be drawn chiefly from that side of it which deals with the lower animals as alive; from a knowledge of them as sentient, often intelligent, and sometimes thoughtful beings, which tends to

greatly broaden and enrich the pupil's sympathetic interest; and from a clear conviction, abundantly supported by observation and experiment, that the principle of the uniformity of nature is not limited in its application to senseless force and matter, but that it extends over life and consciousness as well.

Next, for the sake of clearness in a discussion of the processes of zoölogy with a view to an understanding of their pedagogical bearings, I beg to present a brief general outline of the subdivisions of that science, made for practical rather than strictly critical ends. It will be noticed that some of these subdivisions are practical only and not real,—the division of anatomy, embryology, and physiology, for example, into "external" and "internal," made simply because the methods of study and demonstration are different with respect to those phenomena which may be seen with the naked eye and without instrumental preparation, and those which require the dissecting knife and the microscope or the apparatus of physiological experimentation.

Under "zoönomics" I have intended to include "relations to nature" more commonly so-called, and I have placed this division under physiology to give prominence to the conception of the living group of associated animals as a biological unit, an organism, having its own organs (the smaller groups), its own laws of organization, and its special points of contact with the outer world.

SUBDIVISIONS OF ZOÖLOGY.

1. Animal Morphology (Form).
    - Anatomy.
        - Individual. External. Gross.
        - Comparative. Internal. Minute.
    - Embryology (Ontogeny).
        - Individual. External.
        - Comparative. Internal.
    - Development (Phylogeny).
    - Classification (Taxonomy).

2. Animal Physiology (Action).
    - Adult.
        - Individual. External.
        - Comparative. Internal.
    - Embryological.
        - Individual.
        - Comparative.
    - Social (Zoönomics).
        - Present.
        - Past.
3. Zoölogical Psychology.
    - Individual.
    - Comparative.
4. Zoö-geography (Distribution).
    - Present.
    - Past.
5. Philosophical Zoölogy.

I need not say that this technical arrangement of divisions bears no relation whatever to their pedagogical arrangement. Indeed, a pedagogical arrangement of them is impossible, for I suppose no one would think of teaching all of anatomy before any physiology or the reverse, or, still less, all of development before any classification, and least of all, perhaps, all of the facts of zoölogy before any of the causes of its phenomena, a knowledge of which alone makes it a science in the full sense of the word. Nevertheless, this list will help us to see just what mental activities are aroused and what methods suggested by each of these departments of zoölogy.

Perhaps most of us have many times analyzed the operations of the mind by which such a science is built up, and I will only undertake to distinguish those parts of each division which it is possible to make use of in public school work of a high grade, where zoölogy runs through the course.

That the structure of animals may be thus studied, goes without saying, for many schools study it already,—external

structure by simple observation, and internal structure, gross and minute, by the aid of the scalpel and microscope. I would like to say, by the way, that if a few fair microscopes, a simple microtome, and a few mounting materials and reagents are within reach of the school, there is no reason whatever why the making of serial sections—say, of the earthworm—should not be learned by ordinarily competent pupils who have had some preliminary training in the use of the eye and hand, within three or four weeks of the ordinary time allotted to a class.

Even comparative anatomy, in its elements, is easily pursued in a practical way, by the simple comparison of the structure of two or more animals more or less alike, leading to a distinction of their common characters and a discrimination of those in which they are dissimilar.

Embryology is usually reckoned quite beyond the reach of the common school, and yet a teacher who knows how could certainly demonstrate, by mounted slides if in no other way, the principal external phenomena in the development of a chick. By what is known as the "window method" of demonstration the whole thing could be followed from time to time in a single egg up to the fifth day of incubation, when the development is far advanced. What inexpressible wonder and interest this observation may be made to have, I leave you to imagine.

That a study of the classification of animals is not only possible, as every one admits, but may be made highly profitable to the common school pupil, if properly conducted, I have long been perfectly sure. We must beware, however, of confusing two quite distinct and very different things: the mere learning of a correct classification based on all the facts of morphology as interpreted by the highest zoölogical authorities; and the effort to classify made by the pupil himself, as a practice in generalization. I have yet to learn where in the common school course this training in generalization, this practice in the forming of large and complicated concepts out of concrete materials, in tracing from point to point the threads of the web of relation by which unlike things are unified and made into larger wholes again capable of being compared

among themselves and so built up into higher and higher concepts,—I have yet to learn where this invaluable part of a sound education is now commonly provided for. The doing of this, first on things and then on ideas, is a most profitable exercise, and the habit of doing it spontaneously is a large part of the education of a thinking man.

But in all this matter our animal is perhaps scarcely thought of as alive; indeed this kind of study of it might have been the same if it had never lived at all. But it is as a living thing that it is interesting to the child; as a sentient being that it is unique; as a multiform embodiment and presentment of life that it appeals to us,—an ever-fresh wonder, a mystery never yet explained.

All that may be done with structural zoölogy may be done in some way, sometimes better, sometimes as well, sometimes worse, but still may be done, with the structural side of botany; but there is no teacher's substitute for the living, active animal; neither can anything take the place of the social animal group. The plants of a wood or field or stream are simply a crowd; but the animals of a circumscribed area are a society, built up class upon class, on the vegetable world as a foundation, distinguished by competitions and knit together by the bonds of mutual aid and comfort. Whatever else of zoölogy we may slight or omit, this part, which shows us animals as simply a different kind of men and their organized assemblages as fixed societies, which sets forth and illustrates the natural laws of life and social organization under which we also live and work, must have a place in every well-considered course. As a mere discipline, however, it seems to me on the whole quite inferior to animal morphology. It proceeds by the same methods of observation and comparison, but by processes less refined,—since experimental physiology is practically forbidden for humanitarian reasons,—and yields a less manageable product. It is also far more difficult for both teacher and pupil, but, we must always add, vastly more interesting also.

This dynamic side of zoölogy—its physiology, commonly so called, and its psychology—is really as extensive a subject as its morphological side, and is capable of equal subdivision. The two branches, starting from the same level, run parallel

indeed, one culminating in classification and the other in zoönomics; one leading to the structural group and the other to the social group,—the *lebensgemeinschaft*, or life group, of some of the Germans. And still the two stand in the closest practical relation at every point, structure always explaining function and function explaining structure. I need not say that they are really inseparable in pedagogical practice. And finally I would point out that they both merge, as do all other departments of my subject, in what, on my outline I have called philosophical zoölogy,—in the doctrine of causes, without which, as Ray Lankester well says, no body of facts really deserves to be called a science. How and why came the wing of a butterfly to be covered with scales, the caudal fin of a crayfish to be lobed and jointed, the gastrula of an earthworm to be so similar to that of a lancelet, the eye of a nautilus to be so like and yet so unlike to that of a man? How does it happen that in all Africa there is not a crayfish; that the useless mandible of a butterfly is as constantly present as the indispensable one of a beetle; that through all the ups and downs, the variations to and fro, of the essential conditions of life in any spot, the balance of life remains practically constant for centuries at a stretch? These little words *how* and *why* shed the same penetrating light of thought on this subject as on every other, and may be made to call forth any grade of mental effort, from that of the most obvious inference to the long train of reasoning, checked and tested at every turn by critical comparison with every pertinent fact. But we must not forget, or permit our pupils to forget, that the more general parts of this theory of zoölogy must be taught them *ex cathedra* merely. The real proof of almost any general proposition in zoölogy is the mass of particulars from which, as a generalization, it has been drawn; and the weight of this evidence none but the learned expert can truly judge. It is a weakness of the so-called sciences of observation, from the educational point of view, that their most general conclusions must be taken by the pupil on trust, and that while the process by which these were reached may be illustrated, the evidence on which they rest cannot be commonly reviewed. All the more necessary is it that many small, separate problems in inductive zoölogy should

be worked out thoroughly, and that the methods and results of the pupil's reasoning should be critically tested by comparison with the facts. The difficulties here are, indeed, precisely those of the study of classification, and are to be met by the same expedient of a separation between practice and instruction. The main features of a zoölogical theory may be taught authoritatively, and practical exercises in the method of induction should be devised for their own sake alone.

In all the foregoing I have made no attempt to arrange the matter of a common school course, and I shall be satisfied if I have led you over such a general review of the contents of the zoölogy of the present day as will help to a broad survey of the field, and an intelligent, impartial, and judicious selection from the whole mass of matter offered to the teacher's hand by this rich and many-sided science.

THE RELATION OF THE NATURAL SCIENCES TO THE OTHER STUDIES OF THE COMMON SCHOOL.

F. M. McMURRY. PH. D., NORMAL, ILL.

The relation of the natural sciences to the other studies of the common school leads to the consideration of a very important principle of pedagogy. That principle is applied to some extent by most teachers in each recitation and in each study, but its application farther than that is usually almost totally disregarded.

For instance, under ordinary circumstances, any principal would criticise that teacher sharply who showed, in her recitations, a strong tendency to teach unrelated facts, to marshal forth one point after another without reference to their connections. Such a teacher would rightly be charged with a want of logic, and would deserve to be reminded that the parts of any one recitation should be so related that they seem like parts of a whole, that they form or at least approach a unit.

The same thought applies likewise to each study; its parts are recognized as parts of a rather complete unit and, when taught to a child, it is expected that this relationship will be made apparent. Thus the teacher of arithmetic tries to show that the process of long division is not fundamentally different from that of short division; that percentage is only work in fractions, etc. The teacher of geography does what she can to impart her knowledge systematically; she lets one point lead to another; she shows that the physical conditions of a country determine largely the location of cities, the employment of the people, and the products. She compares the physical features, the occupations and the products of one country with those of another, in order to bring out the salient characteristics more clearly; and she thus binds the facts together till she finally secures something like a unity of geographical knowledge. In other studies the same effort is made; especially

in history is the relation of various thoughts and actions of primary importance, because it, together with literature, is the chief character-building study.

Now, what principle of education is that which demands that the knowledge imparted in each recitation, and in each study as a whole, be *related knowledge?* Or can it be only our æsthetic taste that leads us to admire *unity* and therefore makes this demand. There is a better answer.

Undoubtedly one commonly accepted reason is the view that each study is composed of a classified lot of knowledge. One fact bears a logical or causal relation to another, or there is a close dependency of one thought upon others, or similarity between them; and this relationship of parts, dependency or similarity, leads to classified knowledge, making of the study a connected and inseparable whole. Therefore because the study is composed of classified knowledge it should be *taught* as a related whole; and the recitations, which are separate steps towards the mastery of the whole, should approach, as nearly as possible, small units which, taken together, make it up. There is a strong tendency among all teachers, and especially among specialists, towards the acceptance of this view. And still, few will insist that the branches of knowledge taught in our grammar and primary schools shall be regarded in this light; for several of them, as history, reading, and geography, have not their knowledge classified, *i. e.*, they are not science at all; and those in which the knowledge is classified, as the natural sciences, are not expected to be taught *as sciences* in these schools.

For instance, I think you have agreed that classification is not to be considered as an important purpose in zoölogy or botany. Still, there is a constant effort made to proceed logically, *i. e.*, according to classification, in these studies, and it is proving the curse of many schools. Logical thinking is very desirable in every study, but that kind of logic which leads to the sacrifice of the child for the sake of the study, has no place in the public school.

As far as our common schools are concerned, then, it is not because each study is really an inseparable or organic whole, a science, that we desire to bring its parts into a close relation-

ship. Undoubtedly many who are led to make such an effort, do so from a quite different and more intelligent reason, namely, because *associated* or *related* knowledge is the kind which it is desirable that the child should acquire; the various parts considered in each recitation should be connected because of the superior value of *connected* knowledge; and the parts of each study should be as closely related as possible for exactly the same reason. The very important principle, which was above referred to and which is here involved, is that *the value of knowledge depends not only upon the distinctness and accuracy of ideas, but also upon the closeness and extent of the relations into which they enter. This is a fundamental principle of education*, and especially important in considering the relation of the natural sciences to the other studies of the common school. It was Herbart who said, "Only those thoughts come easily and frequently to mind which have at some time made a strong impression, and *which possess numerous connections with other thoughts*." And psychology teaches that those ideas which take an isolated station in the mind are usually weak in the impression they make and easily forgotten. A fact, however important in itself, if learned without reference to other facts, is quite likely to fade quickly from the memory. It is for this reason that the witticisms, sayings, and scattered pieces of information which we pick up here and there are so soon forgotten. There is no way of bringing about their frequent reproduction when they are so disconnected, for the reproduction of ideas is governed largely by the law of association. One idea reminds us of another closely related to it; this of another, etc., till a long series is reproduced. They are bound together like the links of a chain, and one idea draws another along with it, just as one link of a chain drags another after it. A mental image that is not a member of such a series cannot hope to come often to consciousness; it must, as a rule, sink into oblivion, because the usual means of calling it forth are wanting.

The advantages of closely associated knowledge are thus quite apparent; for it is only by associating thoughts *closely* that one comes to possess them *securely* and have *command* over them. His reproduction of ideas is then rapid enough to enable

him to comprehend a situation quickly and form judgment with some safety; his knowledge is all present and ready for use; while, on the other hand, one whose related thoughts have never been *firmly welded* together, reproduces slowly, and in consequence is wavering and undecided; his knowledge is not at his command and he is therefore weak.

It is because children's related mental pictures are not tightly bound together that they so often jump about helter-skelter and interrupt our recitations by introducing topics wholly irrelevant to the subject matter in hand. One of the foremost duties of their teachers is to associate their knowledge, and thus give them the habit of thinking connectedly, as well as to clarify the old and impart to them new information. Their minds seem to be filled with masses of knowledge that need assortment and systematic arrangement, and this should be arranged in such a way that *chains* of *related* ideas are formed; and these chains, or series, should be run over so often that the reproduction of a portion of any series involuntarily recalls the rest. For instance, the teacher of history should make the causal relations of events so conspicuous in her teaching that if the arbitrary government of George III. be mentioned, a long series of results will almost unconsciously come to the mind of her pupil; as the battle of Lexington, Bunker Hill, declaration of independence, etc.

It is a leading purpose of instruction to form in the minds of children such closely related series of pictures or thoughts; the relation need not be necessarily *causal*, it may be a relation of *similarity* or of *time* or *space*; it may be a logical one, although, as said above, there is danger in too much logic; but above all things it should not be an *artificial* or *forced* relation. Such series are so necessary, because we are governed in our actions by the ideas which we possess; not by the *isolated* ideas which stand aloof from the others, for isolated ideas exert little influence, they lack strength; but by our leading chains of *related* ideas. In deciding upon moral actions a *series* of moral maxims, supported, perhaps, by many individual cases illustrating them come to our minds; and if the maxims composing the series are well enough understood and numerous enough, there is a possibility of their influencing the will sufficiently to

resist temptation. In business and social relations likewise, series of ideas are constantly coming to our minds and deciding our actions. To be moral, to be judicious, to be successful in any line, it is necessary for one to be able to assemble quickly and easily most or all of the knowledge related to the subject in hand ; one who cannot do that is quite likely to act hesitatingly ; and then repent as other considerations come tardily to mind. When knowledge is closely associated it is more thorough, for one point casts light upon another ; and because it is more thorough it is more interesting. When we remember that those facts which are welded together in instruction are better understood, better remembered, more interesting and more effective in their influence upon our actions, we can see ample reasons for imparting knowledge in the related form, in long series or chains of ideas.

Without doubt, the specialist in geography, or history, or science, is somewhat influenced by this consideration when he insists upon the logical development of his subject; but here a great danger threatens the child. For, to take an extreme case, suppose a child has a specialist for his teacher in each branch, as is actually the case, I understand, in the Felix Adler school of New York; each teacher strives to relate the portions of knowledge belonging to his branch as closely as possible; but the very great danger is that the pupil will have a half dozen lots of ideas which will bear very little relation to *one another;* while the parts of each study are well associated, the various studies themselves will stand in no relation to one another.

While the principle is obeyed, that the knowledge imparted to the child should be closely associated, it is at the same time disobeyed in a higher form. For this principle applies as much to the relation of the different studies to one another as to portions of the same study; and, if the different parts of one branch are brought into close relationship because of the superior value of related knowledge, then the same reason exists in a higher degree for the close relationship of all the branches with one another.

The unity of all the knowledge which enters the child's mind is the goal towards which we should strive in the application of the above principle; that is the *highest* unity, and there-

fore the most important. It should be our care, in each day's work, to bring the different kinds of knowledge which our pupil acquires, into a close connection, so that they enter his mind as nearly as possible as a unit. At present this is not the case at all in most schools. During the different hours of the day the most heterogeneous thoughts are crowded into the child's mind in rapid succession. He turns from arithmetic to geography and then reads some prose or poetry; he is next told a mythological story and then receives an information lesson about animals or plants; after this he repeats some newly learned "sentiments," and learns lastly, perhaps, some historical facts. This is about the program followed each day. What a confusion, what a jumble of ideas in his mind, no matter how carefully the portions of each study are associated. The soul itself is a unit, it is said, and tends to hold together and associate its knowledge; but it is helpless before the masses of ideas crowded in upon it in this manner, and we err when we rely upon it for so much help. It is our duty, as teachers, to depend somewhat upon ourselves as well as upon the natural unifying power of the soul; to fix our attention upon the minds of our scholars and see that all the information that we impart to them is as securely bound together as possible. Our efforts will never be crowned with entire success, but we can remedy greatly a serious existing evil. The fact that we do not feel the need of such an effort is no proof that it would not benefit the child. Our broader experience enables us to see some unity in the facts we teach, but with the child this is seldom true, as instruction is commonly given. Most of us can probably remember how astonished and pleased we have been, when, as children, we discovered that a point learned in one branch bore a close resemblance to the lesson in another branch; at least that was my own experience; for, each time I turned from one study to another, I felt that I was going to a wholly different and hence unrelated subject.

We need to keep in mind, therefore, the priuciple pertaining to related knowledge, frequently called the principle of *concentration*, in imparting instruction in our public schools. This does not imply less effort in the future in establishing a close connection between the parts of each study; it means simply

that we should lay *much more stress* than heretofore, upon the relation of the studies to one another.

A good method of teaching will bring about such a relation to some extent, but the chief means of accomplishing this purpose is to be found in the choice of material in the different studies and in its relative arrangement; in other words, the principle of concentration demands a peculiar arrangement of our course of study. Some branches must take the lead and determine partially the choice of material in the others; science must either be the leading study, or assume somewhat dependent relations.

It seems a very serious matter to allow our course of study to be so much affected by the consideration of so comparatively strange a principle of pedagogy as that of concentration; but it is by no means a new principle; for hundreds of years it has had a marked influence upon the school curriculum. Centuries ago, when the number of studies taught in the schools was much less than at present, the humanists, or those who taught the classics, objected seriously to teaching unrelated ideas; they advocated strongly the exclusive study of the classics on the ground that the knowledge thus attained was closely associated and therefore formed a unit in the child's mind. It was with this thought that Comenius recommended that during any one period, as a week or a month and perhaps a term, only a single study should be carried on; for in that way a close connection of the thoughts imparted was assured. It was probably owing to a like reason that others have advocated exactly the opposite course; *i. e.*, that during any recitation all, or at least many, things should be taught, for one thought easily leads to another in a different branch of knowledge, this to another, etc., and thus the knowledge acquired is closely associated in the child's mind. These and similar plans, after having had their numerous enthusiastic supporters, have fallen into ill-repute and been forgotten. To us their defects are quite apparent, because they necessitate either narrow or superficial study, but they should not blind us to the importance of the principle involved.

Two and a half centuries ago, leading educators felt that it was dangerous to teach many subjects, because the ideas

could easily remain disunited and thus unity of consciousness might be destroyed. Since that time most of our common school studies have found their way into our curriculum, and at the present time, another, called Science, is struggling for admission. There is little doubt but that it will soon be generally admitted, and will take rank among the especially important studies. How shall the subject matter in science be chosen? Shall we sit down and make out a course in it without reference to the other school work? If we firmly believe that the ideas which enter the child's mind should be not only *clear* and *distinct* but also *closely related*, we cannot do that. If unrelated ideas were a danger which was carefully to be avoided when there were so few studies, the danger is vastly greater to-day, when our course contains so many more studies; and especial care should be taken to guard against it. It is our duty to seek out the relationship among the different studies and make it plain to the child. As said before, however, this relationship must be a *natural* one; it was because it was made so artificial that the thought of concentration became very unpopular in Germany between the years 1850 and '60, and in consequence most teachers gave up the attempt to relate studies. It is easy, though, to see a close connection between literature, history, and geography, and many teachers now-a-days are making history and geography mutually dependent, and are allowing their history to determine the choice of the poems, orations, etc., which are to be studied in the literature recitations. There is danger, to some extent, of destroying the unity of some of the studies by teaching them in this way; for example, literature, when thus taught, loses its own independence and its different parts will not always stand in much relation to one another; but, in this case, the increased interest in both literature and history and the greater thoroughness obtained, as well as the greatest unity of thought, compensate for the slight loss.

By such an arrangement of studies the series of related ideas formed are not confined within any one study; while one thought in history leads to another in history, as already referred to, series are formed which lead from study to study. For example, the expression, Arcadian farmers, leads our

thoughts to the history of the Arcadians—then to the poem "Evangeline," and finally, perhaps, to the geography of Nova Scotia and the surrounding country. The various studies are thus bound together and reproduced in connection with one another. It is possible to build up such series of ideas where the relation of the different branches is close and natural, so that the choice of material in some is easily determined by the subjects being taught in others.

The question for us now to consider is, whether or not science bears such a relation to the other studies that its dependence upon them, or their dependence upon it, would be natural. Its close connection with language work is plain; the subjects and the contents of many of the compositions may be chosen directly from the science. Its relation to arithmetic is probably as near as that of any other study; in the lowest grades the notions, two, three, four, etc., as well as pairs of twos, threes, fours, etc., can be acquired from science without much special effort, and it is thus a great help to the number work. In the higher grades the science of numbers seems to be largely independent of matter, and it is only now and then that examples may be chosen from science with profit. That we should make our examples, however, more profitable, *i. e.*, more in accordance with our daily experiences, seems generally agreed upon by teachers, and, in that case, science can be relied upon to furnish considerable more suitable material than it does at present.

But what is the relation of science to history, literature, and geography? Must it stand aloof from these important studies, and thus necessitate the existence of a lot of notions in the child's mind, mostly unrelated to the ideas obtained from these other studies? or can it be brought into a complete or even partial relation with them? The subject has been studied so little, and so few attempts have been made in this country to associate science with the other branches, that we hardly know what is possible with us; but that a healthy relation between them can be established to a considerable extent I feel sure. Karl Ritter's fame as an educator is worldwide, and one of his three principles in regard to geography, which has made him famous, was *his assertion of the close rela-*

tionship of history and geography to science. As I understand it, it was his opinion that a knowledge of the plants, animals, etc., of a country is necessary for a fair understanding of the history and geography of that country. If that is true, the relationship is quite close, and its effect upon the branch called science might be to cause the plants, animals, etc., which will be studied to be determined by the country which is under consideration in the geography recitations. For example, when the Rhine is the subject, the grape, its growth and culture, and the making of wine would be excellent subjects for instruction in the science recitations. They would not necessarily have to be treated at just the same time; that might not be convenient; but when they did come up it would be well to teach them in such a connection. It would be well to do so, because the grape is an essential element in the mental picture of the Rhine region, just as corn is essential for the understanding of the geography of Illinois. The knowledge would thus be more *thorough* in each case and, what is exceedingly important, *more interesting*; more interesting because, for some reason, *related knowledge* is necessarily more impressive than unrelated knowledge. It would not be necessary that every subject in science be thus directly suggested by some other study; a certain animal or plant might be suggested, and then others closely related to it, either on account of their similarity or dependence, could be studied. That is the plan which the Herbartian school of pedagogy follows in its selection of science material; some other study necessitates, to some extent, the study of a certain animal, and then it, together with the *group* to which it is for some reason nearly related, receives the attention of the class for some time. By this means a large number of the ideas taught are carefully associated, and then the *habit* of associating knowledge, a habit which must be slowly learned, is acquired.

Each country usually has some characteristic animals or plants, and even if we have not the same at all in our own region, we usually have some nearly related forms which can stand as representatives of the others and be studied in that light. But numerous and apt illustrations of the close connection between geography and science can be the result only of

many experiments in this line. My own efforts towards concentration have been confined almost entirely to the first and second grades, where geography is not taught, and they have aimed at the association of literature and science. In our first grade we have taught fairy tales, and in the second Robinson Crusoe, for nearly one year and a half, ranking both as regular studies which were to be taught each day. We have allowed them to determine the choice of a considerable portion of our material for observation lessons, perhaps nearly half of it. The mere mention of a certain plant in a fairy tale has not, of course, led to its study; but when the part it played in the story was important enough to suggest it naturally as an object of study it was frequently chosen. For instance, the tale "The Pea Blossom" tells first of five green peas in their pod. They gradually change color till they are yellow, when a little boy bursts open the pod and shoots them forth from his pea shooter. One falls into a crack by the window of a poor, sick girl, and one day she discovers a tiny pea vine there. She watches its slow growth, and her enjoyment of the plant and flower brings about her entire recovery. The story directed the attention of the children to the pea; they were interested in the story and to some in extent in the vine, so that the occasion seemed fitting for taking the latter up: the flower, the peas in the pod, their germination and their later growth. Of course the tale was often referred to during these observations. When one remembers how real a fairy story is to a child, he can easily see that observation may be greatly enlivened by such an association.

The story of "The King-Bird," which is the description of a battle between the four-footed animals on one side and the winged ones on the other, led to a careful study of the king-bird and the hornet with its nest, as well as to some study of the bear, fox, wolf, eagle, and several other animals that were kept in a park near by. We might have taught them without the assistance of any story, but it seemed to us that the story was a great help to the science; and besides that, it is certain that the enjoyment of the fairy tale was greatly increased by means of the observations made.

The pine tree, its cones and needles, as well as the leaves of other trees, were studied in connection with the tale called "The Discontented Pine Tree," the tree that was dissatisfied with its leaves, and in consequence received a prettier kind several times. This association of literature and science was certainly natural, and was an advantage to each, while it led to unity of knowledge by developing a series of related ideas. In the second year's work the relation of these two branches seems to me perhaps closer. For suppose a child has reached the point in the story of Robinson Crusoe where he is landed upon the island; if he is to picture vividly, and with proper understanding and feeling, Robinson's thoughts and actions, he must become acquainted with his occupations. He must form a nearer acquaintance with the animals and plants that proved so useful to him, their uses, habits, structure, etc. Strong interest in the story creates the need and desire of knowing more about Indian corn (especially on the part of city children). His pets are the parrot and the goat; they furnish him company and food. They will probably be subjects for study sometime anyway, and it is an advantage to introduce them now while they are objects of interest. He fixes up a sun-dial to tell the time of day; he finds wheat growing before his door and secures a few handfuls from his first harvest; he sows it for several seasons and finally has plenty from which to make flour and bread. But these two processes prove very difficult for him. The island has a tropical climate, a rainy and dry season, and it produces oranges and lemons, cocoa nuts, melons, rice, and grapes, which are made into raisins. Salt is found upon its springs in abundance. Several points which would not come under science proper might well belong to a set of observation lessons for children of this age. For instance, Robinson makes milk into butter and cheese, he invents a calendar, he makes baskets, and he devotes much time to the subject of pottery in the hope of getting vessels to cook in. These subjects, together with those which are nearly related to them, furnish a good portion of the year's work in observation lessons. The related subjects may be of paramount importance. Our class, after becoming acquainted with the plants which grew upon the island, wanted to know how so many ever got there, and

thus the important topic, "the dispersion of seeds," was talked about.

Such a close association of science with literature removes one of the greatest difficulties of which my teachers have complained; namely, the absence of a reason for taking up one subject in preference to another. When there *is* a reason for the choice, the interest of both teacher and pupil is necessarily livelier, the unity of knowledge greater.

I am aware that the danger of artificial associations between science and the other branches is very great; no doubt some of those of which I have spoken will be complained of; I think, too, that if the principle of concentration were accepted it would postpone the choice of a course in science work very much, because we would first have to decide whether science should be made somewhat dependent upon literature, or *vice versa*, and if the former, then a course of literature and history from the first grade to the eighth would need to be decided upon before we could know what our science lessons would be. This is increasing our already exceedingly difficult task; but a very important principle is here at stake. I hope it will occupy the attention of teachers till some arrangement is made to secure a greater unity of knowledge.

It has not been my intention, in speaking of fairy tales and the story of Robinson Crusoe, to advocate them in this paper as school studies; while I do advocate them, my only purpose here was to give some examples of the relationship existing between literature and science.

Before deciding upon the merits of the plan for concentration which I have proposed, it is necessary to inquire to what extent this plan accomplishes the special purpose of science-teaching. For, aside from the great aim of all education, character-building, each study is supposed to have its own peculiar purposes, and any arrangement which tends to defeat these latter may rightly be complained of.

As I take it, the highest immediate purpose of all our instruction in grammar and primary schools is a many-sided interest, and as science represents one of the important spheres of knowledge, its highest immediate purpose is the awakening of a lively and permanent interest in plants, animals, and nat-

ural phenomena, for such an interest is the condition under which the commonly accepted purposes of science-teaching may be effected. These purposes are a habit of observation and the acquisition of a large amount of useful information, and neither of them can be attained sufficiently without a strong and permanent interest in nature. This is so important, because it leads, first of all, to continual mental activity, the chief object of education as far as the intellect is concerned. One who takes delight in nature is continually finding material for thought, for we come in contact with it continually. A botanist, when passing through a wood, is likely to do much more thinking than one who possesses no special liking for flowers, and one who has developed a love for all nature likewise does vastly more thinking, other things being equal, than one who cares little for it.

The connection between a lively and permanent interest and the habit of observation is close. The latter is not a training of the eye simply in the power to look closely and see all ; it is not a *faculty*, which is to be developed in the way we usually think the memory, or a muscle, can be developed, *i. e.* by exercise. A habit is a kind of activity which has become involuntary ; and when we agree that science should impart a habit of observation to children, we mean that we wish them to observe involuntarily or without conscious effort the objects and phenomena which nature exhibits to them. They will never do this to any great degree unless they feel deeply interested in nature. To be sure, practice of the eye is necessary before one can see accurately, but the most important element in this habit is the constant and unconscious willingness to look. It is the absence of such a disposition on the part of most people which prevents them from being good observers. The stock raiser is unconsciously observant of horses and cattle, the shoemaker of the style of one's shoes, the tailor of one's clothes, and the zoölogist of the habits of animals. Our minds dwell upon, and are watchful of those things in which they are interested.

Also, the quantity of useful information that one obtains is largely proportionate to the interest; for a lively and permanent interest in nature causes constant attentiveness to one's

surroundings, and thus produces a continual increase in the store of information at hand.

A person's mental activity therefore, his habits of observation, and his stock of useful knowledge are each directly dependent upon a lively and permanent interest in nature. The plan of study which tends to augment this interest is, for that reason, likely to be approved of by science teachers. As is already clear, one important argument which I have tried to advance in favor of concentration is that it tends to increase the degree of interest in each study concerned. If that is true, the commonly accepted purpose of science-teaching is not defeated by such a plan as that proposed; it is rather made more attainable by it.

Now, if the knowledge that is acquired through science study is not so disconnected in consequence of this plan that comparisons and generalizations cannot well take place, the objections to it may seem largely removed. It is by a study of *method* that the teacher is to surmount this difficulty, for when an object is brought into consideration which is closely related to one already handled, a comparison of the two can well take place. It affords a desirable review; and when several similar objects or phenomena have been treated, even though at rather widely separated intervals, their comparison, the discovery of their common characteristics, and the consequent generalizations, can follow as well as ever. Hence it seems to me that while the dangers and difficulties to be met with in carrying out this idea of concentration are great, its *real* disadvantages are slight; and because an important law of pedagogy demands the establishment of a close relationship among the various studies, concentration of some kind should be attempted.

A COURSE OF SCIENCE STUDY FOR THE FIRST FOUR YEARS: ITS AIM, MATERIAL, AND METHOD.

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At the meeting of the Science Teachers' Section of this Association last year, a committee was appointed to consider the preparation of a course of science study for the common schools of the state, and to report progress at the present meeting. It was the unanimous opinion of the members of the committee that the time has not yet arrived for laying out a definite course of study in these branches. Since it is a fundamental dictum of modern science that valid deductions must be based upon general principles which have been derived from experimental data, and in the matter of elementary science teaching, the experimental data are too few to admit of any broad generalizations, the applications of these general principles to educational work is necessarily limited. While it is true that elementary science teaching has been, and now is, a legislative requirement, it is also true that this requirement has always been based upon the supposed practical importance of a knowledge of certain facts which happen to be included in the material of some of the sciences, and not upon a recognition of the value of scientific training. Indeed, the nature of this requirement has always been such as to preclude the use of the matter taught as a means of training in scientific method.

I shall not, then, attempt to offer a course of study in science adapted to the first four years of school life everywhere, but shall endeavor, rather, to present for your consideration some of the reasons why such a course of study is required, and to suggest, as far as my ability and experience will permit, some of the material adapted to the purpose of such instruction, and some of the methods which I regard as essential to successful work in this line.

It is well, also, to bear in mind that what I shall undertake to say on this subject is intended, as the caption indicates,

to apply only to children in the first four years of their school life,—say from six to ten years of age,—for while the principles of scientific study are the same everywhere, the particular kind of work which a child can do in any subject depends upon his previous training and upon the maturity of his mind. "There is" says R. H. Quick, "between the child of nine and the youth of fourteen or fifteen a greater difference than between the youth and the man of twenty; and this demands a corresponding difference in their studies." The same writer, in speaking of the English school system of the present, says, "As it seems to the present writer, the worst part of our educational course — the part that is wrong in theory and pernicious in practice — is our instruction of children, say between the ages of seven and twelve."

If it is true that the mind of the young child is so different in its capacity for mental work from that of the youth of fourteen or fifteen, it is important that this difference should be clearly understood before attempting to prepare a course of study adapted especially to young children. Fortunately for our undertaking, there is practical agreement among the writers on psychology on this score. No matter what views are held concerning the nature of the mind, it is universally admitted that knowledge can be acquired, broadly speaking, only in two general ways; viz., through the senses or through the imagination. Even our most transcendental psychologists admit that our primary ideas—if not intuitive, and hence incapable of voluntary acquisition—are based upon sense perception. All are likewise agreed that the imagination can work originally only upon these sense perceptions, and later only upon these and the general notions which have been derived by its own activity from sense perceptions. It follows that sense perception must be the first method of the acquisition of knowledge, and that the power of acquiring knowledge by means of the imagination is limited by the stock of sense perceptions which have left their trace in the memory. This being true, the child of six years is still dependent almost entirely upon his senses for the acquisition of knowledge. It follows that the first training of the school should be directed very largely to the cultivation of those powers through which

the child gains the most direct knowledge of things external to him.

This has been recognized and acted upon in some way by every educational reformer from Comenius to Spencer, and our idealistic friends who find in literature and logic the sum total of material for mental training should not forget that John Milton, the greatest literary man of all, has said, * "Because one's understanding cannot, in this body, found itself but on sensible things, nor arrive so clearly to the knowledge of God and things invisible as by orderly conning over the visible and inferior creature, the same method is necessarily to be followed in all discreet teaching."

We have been accustomed to distinguish, at least in thought, between the value of a study as a means of mental growth, and its value as a means of acquiring useful knowledge. The studies of the first years of school life have usually been directed especially to the latter aim, often to the serious neglect of those mental activities which we call the faculties. The little child whose mind is more than at any other time of life open to external impressions through the senses, because he is yet dependent upon these sense impressions for all his mental activity, is shut away from all familiar surroundings in respect to which his mind was so active, and instead of the orderly conning over of visible and sensible things by the method which Milton says "is necessarily to be followed in all discreet teaching," he is set to learning symbols which have, at the best, only a fortuitous relation to the things or ideas for which they stand. When one thinks how wide a departure our primary instruction is from the way in which the faculties are naturally called into play, it seems to me he cannot but agree with Mr. Quick's estimate of the English schools, that "the worst part of our educational course is our instruction of children" during the first four or five years of their school life, and with his further expression of his "strong conviction that boys' minds are frequently dwarfed and their interest in intellectual pursuits blighted by the practice of employing the first years of their school life in learning by heart things which it is quite impossible for them to understand or care for."

* See Quick's "Educational Reformers," p. 84.

It is generally claimed that the training of the mind by means of suitable exercises to the systematic and continuous performance of those activities which, on account of the effort which they require, we call " mental work " is the most important function of the school; and Mr. Spencer, the only educational writer of recent times who seems to exalt the knowledge rather than the training side of education, does so because he believes that the mental activities have been developed from their simplest manifestations in the lower animals through the exercise of the mind in acquiring the knowledge most useful at the time to the individual, and that, consequently, the same kind of exercise will prove most efficient for their future development.

If it is true that training to mental efficiency is the highest function of the school, it becomes important for us to know in what particular line this training can be made most effective with young children. On one point we are all agreed: A faculty can be strengthened only by exercise in the performance of its function. Obviously, then, it is folly to attempt to train the mind in some process for which it has not had the necessary preparation. Counting must always precede addition, and addition must precede multiplication. In the same way, observation and comparison must precede all acquisition of knowledge by means of the imagination. The mind can picture to itself by means of the imagination only those things or phenomena which it has perceived through the senses, or other things and phenomena which differ but slightly from those which it has perceived; and in the latter case, only by comparing the description or picture of the unknown thing or phenomenon with the mental picture of the thing or phenomenon which it has perceived. Clearly, then, a systematic training in observation and comparison becomes a very important function of the primary school.

But comparison has for its purpose the formation of general notions, or concepts, and teaching which does not ultimately lead to general principles and definitions has failed in one of its most important functions. The danger in most cases, however, is not that the pupils will not generalize, but that they will reach their generalizations too soon and from insufficient data,

and that definitions and general principles will be given them to learn, instead of being developed by the natural mental processes of the children themselves. For this reason, the young child should have an extended training in comparing objects and simple ideas before stating the results of his comparisons as general principles. I cannot refrain from laying special stress on this point; for, to my mind, it represents the greatest fault in the reasoning of the whole race. It is not on account of differences in the logical process that such differences of opinion exist on all important questions, but because the generalizations upon which the logic is based have been reached through a different set of experiences for each individual.

Another kind of training which all are agreed that the public school should give is the training to the expression of thought in suitable language. This is important, not only because it enables the child to communicate his thoughts to others, but also because exercise in accurate and elegant expression is one of the best means of cultivating the habit of clear and accurate thinking.

But the training to the expression of thought presupposes that the child has thoughts to express. The repetition of the words of another has long been mistaken by teachers for the expression of the thought which originally called forth those words; but since Mr. Edison has so successfully accomplished this operation by machinery, the importance of training children to it has been much diminished, and it is becoming quite generally admitted that the demands of the day are for people who can speak their own thoughts with clearness and directness. But we have before seen that to awaken the mental activity of children and thus make possible the expression of thought, we must appeal largely to their sense perception; consequently the conditions most favorable to training in observation and comparison are also best suited to train the children to the expression of thought.

Up to this point, it would seem that there can be little difference of opinion as to the nature of the mental training which should be given by the primary school. It should unquestionably train the child in the performance of those

processes upon which he is dependent for all his knowledge at the time and by which he must acquire all the materials for his future mental acquisitions, and it must give training in that process by which he is enabled to communicate his thoughts to others and, in turn, acquire a knowledge of other people's thoughts, and by which process he, at the same time, gives definiteness and permanence to his own ideas.

But this is not the whole of the work of the primary school. The child must also be taught those things which are the most important for him to know as a preparation for life, and without which his means of mental acquisition would always be those of a child. In other words, he must be taught the facts of his relation to the rest of the creation, without which knowledge he will be seriously hampered in the struggle for existence; and he must master the means of communication afforded by written language.

To my mind, then, the functions of the primary school are as follows: It must train its children in the process of acquiring knowledge through the senses, in the process of comparison, by which process only it is possible to arrive at general notions, in the process of expressing thought in suitable language, by which means only the child can communicate with other persons, and by which his own ideas attain a definiteness and permanence which could be acquired in no other way; and it must aid the child in acquiring that knowledge of his relations to other beings and to the forces of nature which is most important to him at this stage of his life, and must give him the means of communicating with other minds which is afforded by written language.

In deciding upon the material most suitable for the purposes just outlined, several considerations must be kept in mind. First, and most important, the material must of itself be interesting to the child. Sully says, "There is no distinct thinking, no vivid feeling, and no deliberate action without attention. This co-operation of attention is especially conspicuous in the case of the *intellectual* operations." And it is clear to all of us that without this active co-operation of the mind, no intellectual activity worthy of the name can take place. But we attend only to those things which interest us. Who

of us has not, under the imperative command of the teacher to pay attention to the lesson, cudgeled his brain until his nervous force was exhausted in the vain effort to set in motion some train of mental activity which was for the time entirely beyond his control? And who has not, in a similar manner, ignominiously failed to drive from his mind some train of thought which for the time had an overpowering interest for him, that he might attend to the work which the ruling powers of the school had decided was best adapted to give suitable exercise to his mental faculties?

It is true that by an excessive expenditure of nervous force we may be able to fix our attention for a time on things not of themselves interesting to us, but in this case, on account of the excessive exhaustion of nervous energy, the attention cannot be long sustained. Indeed, I believe that most of my audience will agree that the principal cause of exhaustion of their mental energy in school was due to their efforts to pay attention to things which had no interest for them. It is plain, then, that if the studies of the primary school could be based upon material which would of itself call forth the mental activity for which children of that age are so noted outside of school, it would insure a great saving of nervous energy on the part of both pupils and teacher, besides assuring a proper exercise of those faculties which it is the province of the school to cultivate.

But it is not enough that the material selected for primary teaching should be interesting to the children. One of the principal functions of the school is to give useful knowledge. The knowledge of most use to the child, as well as to the man, is the knowledge of his relations to the universe in which he lives. These relations must, in great measure, be learned by experience; and since only the most simple relations are apparent to children of primary school age, the material studied by the child must be that which is most nearly and plainly related to him. Again, it is not enough to determine what material would be most useful to children could it be provided for them. Any course of study prepared for the primary schools of the state must be based upon material which is everywhere easily obtainable.

The first important question, then, which presents itself for our consideration is, What material most nearly fulfills the above requirements? I am sure that all will agree with me that the material which is generally used as a basis for the instruction of the primary schools answers to only one of these requirements; viz., it is easily obtained. Even in the best school systems of the state, a very large proportion of the time of the first two years is taken up in teaching the children to read from books. Important and necessary as this acquirement is, it does not accomplish any of the purposes of mental training to which we would attach so much importance. The sense training which a child gets in observing the one or more words which are selected as his lesson for the day, when compared with the number of equally good and careful observations which he would make in the same time outside of school, sinks into insignificance. The comparisons which it is possible for him to make between the words which he is learning are too few to dignify with the name of mental exercise; the number of new ideas which he acquires is zero, because it is a dictum of primary teaching that the symbols to be learned must be those which stand for familiar ideas, or, in other language, the first words which the child learns to read must be those which are already in his vocabulary; and the opportunities for the expression of thought may be reduced to a minimum by closing the senses — the only avenues by which thought can be awakened in children of this age — to all interesting, and hence natural, stimuli. And yet every one is sorrowfully contrasting the language expression of the play-ground with that of the school-room, and we never attend an institute or a teachers' association that we do not hear some one explain his new and improved method of teaching children to read with natural expression.

To those teachers who recognize the necessity of providing some means for calling forth the mental activities of the children under their care, two kinds of material have been suggested; viz., the consideration of natural objects and phenomena, and the study of the imaginative story. While nothing is farther from the mind of the writer than to say anything which could detract from the undoubted educational value of

imaginative literature as a means of training in language, and its still greater value as a means of inculcating moral truths, yet it would seem that for the purposes of primary instruction as outlined in this paper, the natural sciences offer a still more valuable material. If it is true that the training to the acquisition of accurate knowledge through the senses should precede the training to the acquisition of knowledge by means of the imagination, then the study of natural objects and phenomena should precede the study of imaginative literature. It is also true that the attempt to build up in the mind of the child by means of the imagination pictures of objects and phenomena differing widely from his experience, can end only in a wretched confusion of indistinct mental images.

One of the mental weaknesses of childhood is the inability to distinguish between the memory of a sense perception and the memory of a picture which has been built up by the imagination. It is on account of this weakness that children are so generally untruthful. The same weakness exists among people of limited civilization throughout the world, and is the cause of many of the myths and superstitions which have come down to us as history. If the training of the school-room is such as to give undue importance to these imaginary objects and phenomena, this weakness is still further exaggerated; and if, in connection with this, the imaginary objects and relations are untrue to nature, the child is being educated in superstition. It would seem, then, that while the carefully selected fairy tale may become, in the hands of the thoughtful teacher, a valuable means of mental and moral training, in the hands of the less thoughtful teacher, it may degenerate into an instrument of positive harm to the child; and that in no case can it give the mental training most important to the child of the primary school age.

The natural sciences, on the other hand, seem to provide the material which fulfills more nearly than anything else the requirements which we have laid down. In the first place, they provide the material most interesting in itself to children. It is unnecessary to argue this point before an audience of observing teachers. No one has failed to notice the mental activity called forth in children by birds and butterflies, flow-

ers and pebbles, the rainbow and the snow storm. Especially is this interest manifested in living beings, and one of the chief sources of the child's interest in his inanimate playthings is in attributing to them the functions of life. If we can learn anything from the teachings of nature, it is plain that living animals provide the best material for calling forth in a natural manner the mental activities of children.

But since we wish the ideas which the child acquires from his study to be useful to him, and since the most useful ideas are those which are concerned with our relations to the universe, of which we are a part, we have decided that the material selected for the child to study must be closely related to him, and in such a way that he can discover for himself the relation. Please do not understand me to say that the moral relations of the child to his fellows, and his religious relations to the Creator are of less importance than the so-called physical relations of the child to his environment; but these, being abstract, and difficult or impossible to teach to a child by experience, are not suitable subjects for primary instruction, except as they can be taught incidentally, Many of the relations between the child and the living animals most nearly like him are, on the other hand, easily discovered by him; and while they provide exercise in the processes of observation and comparison, they also furnish suitable material for training to the expression of thought. This is especially true if the observations and comparisons are directed to phenomena rather than to bodily structure. In the opinion of the writer, the principal reason why so little success has been achieved in primary science teaching is because the whole attention of the children has been directed to the observation of structure with a view to classification, rather than to those phenomena which are common to the child and the animals which he is studying, and which are, accordingly, of themselves interesting to him. If it is true that living animals are more interesting to the child than inanimate objects, it is because the phenomena of life are more interesting to him than the facts of structure, and hence it is important that the study of the functions of animal life should precede the study of the structure of animal bodies. By means of the interest awakened in this part of the

subject, the attention can readily be carried over to the study of the structures which are associated with a given function. In this way, the studies of comparative physiology, psychology, and anatomy go hand in hand from the first, and all the knowledge acquired by the child has that systematic relation to all his other knowledge which is characteristic of the material of a true science.

The importance of this order of study is still more manifest when we attempt to use the material derived from the observations of the children for teaching reading and language. Since the chief functions of animal life are similar in the child and in the animals which he is studying, the vocabulary which he will use in expressing his thoughts will be limited and the words will be often repeated in new relations, thus furnishing excellent material for the preparation of reading lessons. In the language-training of the primary grades, one of the most important objects is the cultivation of the power of continuous thought and expression. It has been a valid criticism of much of the language-training based upon the study of science that it consisted of disconnected and unrelated statements. This was necessarily true as long as the children were trained to make disconnected observations, and in describing the parts of an animal or plant only disconnected observations are possible.

The one essential requisite for continuous discourse is continuous thought. To awaken continuous thought, the material used must arouse an abiding interest, and each observation must be so related to those which have preceded it and those which are to follow it as to make a coherent whole. If the observations are directed to the way in which certain functions of animal life are performed in different animals, or to the relations between a certain function and the structures by which it is performed, we have such a coherent series of observations, and the train of thought awakened by them is necessarily continuous. It is generally conceded that no relation of ideas is more efficient in aiding the mind to recall past experiences or conclusions than the association of cause and effect. In the series of observations and conclusions which we have been considering, the relation of cause and effect has been the central thought upon which nearly all the observations and compari-

sons have been based, consequently the notions formed are all related to each other by this most suggestive association, and become in reality a continuous train of thought which can find expression only in continuous discourse.

It seems, then, to the writer, that the natural sciences, and among the materials of natural science, living animals, fulfill most satisfactorily the requirements of a suitable material for primary instruction. They are naturally interesting to the child, and hence awaken his spontaneous mental activity; they are closely related to him and to one another, and in such a way that he can discover the relations, and hence they provide for suitable exercise in observation and comparison, and the generalizations which he makes are of the kind most useful to him, because they are concerned with his relations to the world in which he lives; the notions derived from their study may be so related to each other by the association of cause and effect as to form a continuous train of thought and to find expression only in continuous discourse, and on account of the limited number of words needed for their expression they may provide excellent material for the preparation of reading lessons; and, finally, this material is so universally distributed as to be within the reach of every one.

What has been said of living animals is also to a large extent true of plants and, in a less degree, of minerals. In both of the last-mentioned departments of natural history, there is also frequently a marked æsthetic interest, due to the beauty of the flower or the crystal. In the case of plants, this study of the relation of function to structure may still be pursued with great interest. The relations of dependence between animals and plants may well furnish the starting point for the study of botany, and the interest which has been aroused in the study of animals may thus be carried over to the study of the nearly related plant. In this line, the study of insect fertilization of plants and the adaptation of the structure of plants to the performance of this function may well furnish a very interesting and instructive chapter. Among the subjects which botany alone offers, the study of plant germination, concerned as it is with the apparent beginning of a new life, is

always interesting to children of all ages, and seems to have a peculiar attraction for even the trained biologist.

This study of the inter-relations of the great groups of organic beings will soon lead the pupil to see that as animals must feed upon plants and other animals, it is important for the preservation of both the plants and animals which are used for food that they have some rapid way of reproducing their species and some means of protecting themselves from their enemies, and then the study of the ways in which plants and animals protect themselves from their enemies becomes one of the best imaginable fields for observation and comparison. And thus we might enlarge upon our subject, and we should still find that each observation and generalization but paves the way for another, and that since each observation is closely and naturally related to the whole series of observations which have preceded it, the interest is cumulative throughout the whole series.

It is also worth our while to note that the ideas which the children derive from this study are the fundamental notions of modern thought. The political economy, the religion, the ethics of to-day are permeated with the notions derived from the study of the natural sciences, and in so far as they differ from the politics, religion, and ethics of the past century, this difference can be traced to the spread of scientific ideas, the education of the people in the scientific method of thinking, and the more general acceptance of that greatest of all scientific inductions, the belief in the uniformity of nature. Thus we are paving the way from the first for the development in the mind of the child of the most fruitful concepts of modern thought, while we are training him in that method of thinking which, more than anything else, distinguishes the great minds of to-day from those of the past.

Thus far we have discussed the aim and material of our primary course in science; it yet remains to say a few words about the method of instruction. I approach this phase of the discussion with reluctance, because to those teachers who appreciate clearly the aim of this fundamental primary work, the method of accomplishing this aim is self evident, while those who teach without a definite aim are sure to have some pet method of instruction which they feel called upon to explain

and defend upon the slightest provocation. It accordingly happens that the discussions in our teachers' meetings nearly all turn upon something that has been said concerning some more or less popular teaching device, rather than upon the educational principles involved. I shall, accordingly, try to limit my discussion of method to those points which seem essential to the accomplishment of the proposed aim. And the first proposition which I wish to make, and the one which meets with the severest criticism from many of our prominent educational writers, is this: scientific training cannot be acquired from the study of a text-book. It would seem unnecessary to mention this point in connection with primary instruction, were it not for the fact that there are already several books in the market which are intended to give children this elementary scientific knowledge of which we have spoken, without the effort of observing and reasoning on the part of the children, and many of our leading writers on educational subjects still indorse this "labor-saving" method for older pupils. We have, however, tried to make it plain that this mental exertion on the part of the child is the one thing above all others which we wish to encourage. Anything, then, which comes between the child and the objects of his observations and comparisons is a hindrance rather than an aid. We have maintained that the expression of the child's own thought in suitable language is something to encourage, and we all know that any method by which a thought becomes associated only with some set form of words is a hindrance to freedom of expression. We believe that the cultivation of an abiding interest in the works of nature, and especially a sympathetic interest in living beings, is one of the greatest functions of education, and we know that to become thoroughly interested in any object, we must become well acquainted with it. And so we might go over the whole ground. The chief aims of science study are defeated by approaching the subject by the literary method.

Do not understand me to say that I would keep the children from reading books about science. The more they are interested in scientific studies, the more scientific books they will want to read, and the more they should read. To the child who has become interested in the study of animals and plants,

one of the chief incentives to learn to read and write is that he may be able to learn of the observations of others, or may record his own observations.

Neither do I wish to be understood as indorsing any of the bosh which the opponents of science study put into the mouths of hypothetical writers on science teaching, and then proceed to criticise; such, for example, as " Never tell a child anything which he can find out from his own investigation." There are times when children need to be told many things which they cannot afford to find out from their own experience. What I do wish to repeat, and the oftener and the more emphatically the better, is that the interposition of a text-book or verbal description between the child and the subject of his observations and comparisons is fatal to all real training in observation, comparison, and expression.

But there is another method of teaching which, while it is indorsed, at least in theory, by many good teachers of science, seems to me also to defeat some of the chief aims of primary study. It is the method of allowing the children to make observations for themselves, entirely undirected by the teacher. It is based upon the notion that it is not natural for children to observe or think systematically, and hence it is going contrary to nature to train them to systematic observation and thinking. While it is undoubtedly true that children in their play do not make systematic observations, and that the habit of systematic observing and thinking belongs only to the trained mind, either of the child or the adult, we should not forget that it is exactly this difference between the trained and the untrained mind which we, as teachers, are trying to produce. It is like the notion of giving the child only the fanciful in literature to read, because he has not yet learned to distinguish it from the representation of the real. Mental efficiency in any line means the power of systematic and continuous thinking in that line, and it is agreed by all that one of the chief functions of the school is to train to mental efficiency.

But if we are not to tell the children what to see, how are we to direct their observations? The answer is simple. Children may be set to making observations and comparisons for the purpose of finding the answer to some definite question

which has been suggested by themselves or their teacher. But allow me to say emphatically that children should never be set to going through the form of finding out things which they know perfectly well already.

The true work of the science teacher is to suggest to the children questions the answers to which they must find out from their own investigations, and which will be of value to them. And this is by no means a simple task, as any one will testify who has tried to arrange such a set of questions for a single class. A course of study in this sense will be such a set of questions adapted to the condition of the pupils; a set which will tax their powers enough to insure a development of strength, but will not be so difficult as to discourage them; which will increase their stock of useful knowledge, but will not lead them so far from familiar ideas as to cause them to lose sight of their relations, and hence to lose interest in the subject; and which will, at all times, be adapted to the material at hand. These and the many more considerations to be kept in mind, make the preparation of such a course of study extremely difficult for even a single class, and I feel sure that you will pardon me for not presenting such a course of study adapted to all the schools of the state. It is apparent that such an outline of study can be of value to others than the one by whom it was prepared only as a means of suggesting work which they can adapt to the needs of the classes under their charge. Such a course, worked out by a practical science teacher and tested with his classes, would be of great value to teachers who have no definite notion of the capabilities of children for doing this kind of work. Some commendable outlines of this kind have already been prepared, the most important one I have seen being the "Outlines of Natural Science" published by Prof. Wilbur S. Jackman, of the Cook County Normal School. More encouraging to me, however, than any outline of study is the work which is being done by teachers throughout the state, from the best primary schools of cities to the "little red school house" on the prairie. And it is a pleasure to know that in facilities for doing this work, the country school ma'am is as well equipped as her more pretentious sister of the city, and I am happy to

know that many country school teachers are undertaking this work intelligently and successfully.

While I shall not, then, attempt to offer an outline of study for the primary schools of the state, it may be well, even at the risk of tiring you with repetitions, to mention some of the considerations which must be kept in mind in preparing such an outline and in presenting it to pupils.

First, since it is important that the child should learn as early as possible the significance of the most important of his bodily functions and their relations to the structures by which they are performed, and since the easiest and most interesting method of doing this is by comparing himself with some nearly related animal which performs the same functions in a similar manner to himself, the first animal selected for study should be one closely related structurally to the child. It would accordingly seem best to begin observation work with one of the higher mammals.

Again, since the study of action should precede the study of structure, the animal selected for study should be not only alive, but active. The squirrel seems to fulfill the above requirements as well as any of our common animals, and is easily obtained and easily kept.

Since the training in comparison should occupy such a prominent place in our method, this first animal should not only be compared with the child, but with other similar animals with which the child is already familiar. By this I do not mean that he should be led to "discover" that "A squirrel has four legs," "A horse has four legs," "A dog has four legs," etc., etc. Neither should I care if he did not learn that all of the above mentioned animals have back-bones, and hence are called vertebrates. But a legitimate series of questions could be made, for example, on the comparisons between the kinds of food eaten, the methods of obtaining food, and the adaptation of structure to the capture or collection of food in the case of each of the animals mentioned. Then, as some of the animals studied serve as food for other animals, a series of questions as to how each animal escapes or defends itself from its enemies; where it makes its home, and why; what advantage, if any, it gains from its color, and the like, might advantageously follow

the first series. For some of the lines of comparison just outlined, the squirrel and rabbit would furnish excellent material to those pupils who are somewhat acquainted with their habits of life. While both must provide themselves with similar food and must escape from similar enemies, their méthods of doing both are quite different, and the comparison of these habits and the structural differences accompanying them could be made a very fruitful subject for consideration by primary pupils.

After the child has begun to appreciate the fact that animals, and plants as well, do not always live under the conditions most favorable for their existence, but that the habits and conditions of life of most animals and plants are those which have been forced upon them by other animals and plants in the great struggle for food, he will ever afterward be interested in observing the manifold variations of structure which have become necessary to adapt each animal for obtaining food and air in that particular part of the earth which it is compelled to inhabit. And this great principle is not beyond the comprehension of primary children, as many teachers have seen evidence to prove.

In passing downward in the scale of animal life, it seems best that each step should be made comparatively short and easy, especially at first. It is well known that children notice resemblances much more readily than differences. This is shown in the fact that they regularly apply to new and strange objects the names of known objects which resemble them. This being true, the animals selected for these early comparisons should have many points of similarity.

What has been said is sufficient to suggest the line of questioning which seems best adapted to calling into activity the faculties which we wish to train, and to directing the attention of the pupils to that line of thought which will be most interesting and most useful to them in after life, as well as at the present time. It yet remains to show how the material furnished by this study can be used as a basis for language-training, and for teaching reading. This part of our subject, however, seems to require but little attention on our part. For oral language-training, the value of this work is at once apparent. If the lesson has been properly assigned, the children,

when they come to the recitation, have thoughts which they are ready and anxious to express, and, providing their attention is not continually drawn from the subject in hand by commenting on their use of language, they will speak as fluently and naturally as on the play-ground. The conditions for expression are, in fact, almost ideally favorable. The child has become possessed of some information which he is anxious to impart to his teacher and his fellows, and his audience is present and equally anxious to learn of his discovery. For written composition, at a later stage, the material is just as valuable, and if the habits and mode of life of some animal or animals be taken for a subject rather than the description of the structure of some animal, there will be no difficulty about continuous thought and expression, providing always that the child knows from his own observations what he is asked to tell in composition.

The method of teaching reading from object lessons has, in one form or another, been before the teachers so long that they will have no difficulty in seeing how this material is especially adapted to that work. The mechanical features of the older methods are eliminated by giving the children reading material which embodies their most recently acquired and most interesting thoughts. They are not memorizing the symbols of words which suggest no thought to them, or, worse yet, the amputated members of words which cannot possibly express an idea, much less suggest one to anybody; but they are learning a new method of expressing and preserving the thoughts which are at that particular time of overwhelming interest to them.

Please bear in mind, however, that this method is not suggested as a device for teaching reading, but that the teaching of reading is recognized as only one, and not the most important one at that, of the aims of primary instruction, consequently the question as to whether a child will learn to read as rapidly by this method as when his whole time is taken up with some device for learning to read, has no bearing upon this discussion. I am happy to say, however, that among the teachers of my acquaintance who have tried to teach reading in this manner, there is a universal agreement that the child

will learn to read as early by this method as by any other. I do not, as I said before, mention this as one of the chief merits of the method, but because the chief objections generally urged against it come from the fact that it renders useless somebody's little reading device.

And now, in leaving this subject in your hands for discussion, I wish to ask you to condemn mercilessly any false doctrine which I may have uttered, but to meet the question fairly, as I have tried to state it, on the grounds of the accepted principles of education. And if you believe, as I do most emphatically, that this subject of primary instruction in science is one of the most important subjects that can come before us as teachers, let me ask you to give it your earnest consideration for at least one year, that we may come to the next meeting of this Association much better prepared than at present to decide upon a course of science study for the first four years of school.

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